INTERVENTIONAL PAIN SURGERY

Editors:
Kai-Uwe Lewandrowski
William Omar Contreras López
Jorge Felipe Ramírez León
Álvaro Dowling
Morgan P. Lorio

Bentham Books

Neuroendoscopy and Interventional Pain Medicine

(*Volume 3*)

Interventional Pain Surgery

Edited by

Kai-Uwe Lewandrowski

Center for Advanced Spine Care of Southern Arizona and Surgical Institute of Tucson, Tucson, AZ, USA

William Omar Contreras López

Clínica Foscal Internacional
Autopista Floridablanca - Girón, Km 7, Floridablanca
Santander, Colombia

Jorge Felipe Ramírez León

Fundación Universitaria Sanitas
Bogotá, D.C., Colombia

Álvaro Dowling

Orthopaedic Spine Surgeon, Director of Endoscopic Spine Clinic Santiago, Chile

&

Morgan P. Lorio

Advanced Orthopedics, 499 East Central Parkway
Altamonte Springs, FL 32701, USA

Assistant Editors

Hui-lin Yang

Professor & Chairman of Orthopedic Department
The First Affiliated Hospital of Soochow University
No. 899 Pinghai Road, Suzhou, China

Xifeng Zhang

Department of Orthopedics, Wangjing Hospital
China Academy of Chinese Medical Sciences, Beijing, China

&

Anthony T. Yeung

Desert Institute for Spine Care
Phoenix, AZ, USA

Neuroendoscopy and Interventional Pain Medicines

(Volume 3)

Interventional Pain Surgery

Editors: Kai-Uwe Lewandrowski, William Omar Contreras López,

Jorge Felipe Ramírez León, Álvaro Dowling & Morgan P. Lorio

ISBN (Online): 978-981-5274-52-3

ISBN (Print): 978-981-5274-53-0

ISBN (Paperback): 978-981-5274-54-7

First published in 2024.

Bentham Science Publishers Pte. Ltd.
80 Robinson Road #02-00
Singapore 068898
Singapore
Email: subscriptions@benthamscience.net

ENDORSEMENTS

SICCMI (Sociedad Interamericana Cirurgia de Columna Minimamente Invasiva)

Founded in 2006, SICCMI aims to advance and mainstream minimally invasive spine surgery (MIS), aligning with the objectives of Neuroendoscopy & Interventional Pain Medicine. Our members have worked to implement MIS throughout South America, the Caribbean, Central America, and North America. Many of our key opinion leaders perform endoscopic surgery at the highest level and have contributed to this comprehensive multi-volume text. Four of the editors hold leadership positions within SICCMI. The table of contents is extensive, covering the cervical and lumbar spine and advanced technological applications. This book will serve as the core curriculum and course material for endoscopic spine surgery within SICCMI. It is my pleasure to endorse it on behalf of our society.

Alvaro Dowling

Past President of SICCMI

ISASS

The origins of the International Society for the Advancement of Spine Surgery (ISASS), formerly known as The Spine Arthroplasty Society, can be traced back to its focus on motion preservation as an alternative approach to fusion. Over time, ISASS has remained dedicated to its overarching mission of serving as a worldwide hub for scientific exploration and education, centered around the needs of surgeons.

ISASS was established with the primary goal of creating an impartial platform where experts could openly discuss and tackle various aspects of both fundamental and clinical research related to motion preservation, stabilization, cutting-edge technologies, minimally invasive procedures, biologics, and other crucial subjects aimed at restoring and enhancing spinal motion and function. The society boasts a diverse and thriving global membership consisting of orthopedic and neurosurgery spine surgeons as well as scientists.

ISASS stands committed to pushing the boundaries of spinal techniques and procedures, including groundbreaking approaches like endoscopic spine surgery. A testament to this dedication is this text, Neuro-endoscopy, which serves as a reservoir of knowledge contributed by experts, resulting in a comprehensive and current reference text. This publication stands as a tangible example of our unwavering commitment to surgeon education and scientific advancement.

As representatives of ISASS, we take great pleasure in endorsing this all-encompassing text. It is a true reflection of our society's tireless pursuit of enhancing surgical education and promoting rigorous scientific exploration.

International Society for the Advancement of Spine – forging ahead on the path of progress.

Huilin-Lin Yang MD, PhD

ISASS Co-President, International 2023-2024

Morgan P. Lorio MD, FACS

Co-President Elect, USA 2024-2025

DR. KAI-UWE LEWANDROWSKI
AMCICO ENDORSEMENT
Neuroendoscopy and Interventional Pain Medicine

Asociación Mexicana de Cirujanos de Columna A.C.

Dear Dr. Lewandrowski:

On behalf of the board of Asociación Mexicana de Cirujanos de Columna A.C (AMCICO) it´s an honor to endorse your upcoming groundbreaking text entitled *Neuroendoscopy and Interventional Pain Medicine*.

Your editors and authors highlighted the advancement and mainstreaming of minimally invasive surgery (MIS) for various topics in neurosurgery, spine surgery, and novel interventional pain management strategies involving the endoscopic technology platform. AMCICO members recently joined to discuss the implementation of MIS endoscopic surgery techniques in Mexico, where many of its key opinion leaders, some of whom have contributed to this outstanding text, perform endoscopic surgery at the highest level. The book content is exhaustive and comprehensive, encompassing cervical and lumbar spine topics with advanced technology applications. Moreover, your text highlights endoscopic surgery techniques of the cranium and skull base and, for the first time, describes the prenatal intra-uterine endoscopic repair of spina bifida. Neuroendoscopy and Interventional Pain Medicine will serve as AMCICO's core curriculum and course material for endoscopic surgery of the spine and neurological system. It is my pleasure to endorse it on behalf of AMCICO.

Again, we thank you for your valuable academic contribution and reiterate our disposition to assist with disseminating your outstanding text.

Sincerely

Dr. Eulalio Elizalde Martinez

President of AMCICO

Junta Directiva 2021 - 2023

SILACO (Sociedad Ibero Latinoamericana de Columna) had its beginnings in the meetings of the Scoliosis Research Society with the first Hispano-American Congress held in 1991 in Buenos Aires Argentina.

Since then, it has morphed into an organization that promotes the study of treatments and prevention of spinal conditions by bringing together spine care professionals from all subspecialties.

The scientific activities of our biannual Ibero-Latin American Congress are focused on the promotion of surgeon education to the highest academic standards via international relationships between members from the Americas, Spain and Portugal.

Neuroendoscopy and interventional Pain Management resembles such a collaborative effort where authors worldwide have come together to update the reader on the latest endoscopic spinal surgery techniques.

SILACO has incorporated Neuroendoscopy and interventional Pain Management into its core curriculum and plans on using it as course material for its continuing education courses.

It is my pleasure to endorse it on behalf of SILACO.

Dr. Jaime Moyano
President of SILACO

Editor SEOT Magazine
Ecuadorian Society of Orthopedics and Traumatology – SEOT

SOMEEC - Sociedad Mexicana de Endoscopia de Columna

SOMEEC - Sociedad Mexicana de Endoscopia de Columna – is Mexico's prime organization uniting spine surgeons with diverse training backgrounds who have a fundamental interest in endoscopic surgery. SOMEEC organizes annual meetings where member surgeons and international faculty update each other on their latest clinical research to promote spine care via endoscopic spinal surgery techniques. Two of the senior lead editors of Neuroendoscopy & Interventional Pain Medicine have been active international supporters of SOMEEC. I am pleased to endorse their latest three-volume reference text, Neuroendoscopy & Interventional Pain Medicine which will become an integral centerpiece of SOMEEC's continuing medical education programs.

Enrique Saldívar Farrera

President of the Sociedad Mexicana de Endoscopia de Columna

Roberto Cantu, Jr. MD

Vice President of the Sociedad Mexicana de Endoscopia de Columna

Academia Nacional de Medicina de Colombia

The Academia Nacional de Medicina de Colombia recognizes the high academic and scientific value of the comprehensive three-volume text Neuroendoscopy & Interventional Pain Medicine. developed by leading figures in the field—including our esteemed members of our Academy, Dr. Kai-Uwe Lewandrowski, William Omar Contreras, and Dr. Jorge Felipe Ramirez—represents a significant advancement in minimally invasive spinal surgery. It will undoubtedly serve as an essential resource for both current and future spine specialists, greatly enhancing clinical practice and patient outcomes.

Gabriel Carrasquilla MD, DrPH, MPH, MSc
President, Academia Nacional de Medicina de Colombia

Asociación Colombiana de Neurocirugía (ACNCx)

The Asociación Colombiana de Neurocirugía (ACNCx) is a non-profit, private legal entity dedicated to promoting the scientific and ethical development of neurosurgery in Colombia. Established in 1962, ACNCx is committed to advancing professional responsibility, continuous improvement, and the highest standards of patient care. ACNCx operates with a democratic structure, upholding principles of solidarity, unity, and participation. Our association is deeply involved in the education and advancement of neurosurgical practices, including innovative procedures such as prenatal endoscopic repair and endoscopic interventions for the brain, neuroaxis, and spine.

It is with great pleasure that I endorse Neuroendoscopy & Interventional Pain Medicine on behalf of ACNCx. This book highlights the groundbreaking work of Colombian authors and serves as a valuable resource for our members and the broader neurosurgical community.

Best Regards,

Alberto Dau Acosta

President

Colombian Association of Neurosurgery

International Society for Minimally Invasive Spine Surgery (ISMISS)

The International Society for Minimal Intervention in Spine Surgery (ISMISS) brings together spine surgeons from all over the world united by the constant strive for advances in minimally invasive techniques. Since its conception in 1988 on the occasion of the GIEDA-Bruxelles meeting, international coordination of educational, instructional, and scientific exchanges in minimally invasive spine surgery has been the highest priority for prior and current directories.

As the newly elected president of ISMISS, it is my great pleasure to endorse Neuroendoscopy & Interventional Pain Medicine as an extraordinary textbook of up-to-date collaborative expertise in endoscopic techniques of the spine and neuroaxis. I am convinced that it will contribute significantly to the educational process of future spine specialists.

Prof. Dr. Joachim Oertel

President ISMISS

Chinese Orthopaedic Association (COA)

Chinese Orthopaedic Association (COA), a specialty society within Chinese Medical Association, was founded in 1980. It aims to promote scientific exchange, provide orthopaedic education, and improve patient care. COA is the largest and most influential orthopaedic society in China, equivalent to AAOS in the US. Its annual meetings attract about 15,000-32000 attendees, including world-class experts, presidents of international orthopaedic societies, and leaders from national orthopaedic associations.

In line with its mission to foster global discussions and enhance surgeon education, it is my pleasure as Chairman of the COA MISS Society to endorse Neuroendoscopy & Interventional Pain Medicine. This comprehensive text, created by an international team of editors and contributors, including many from China, provides an expert update on the latest endoscopic spinal surgery techniques.

I am confident that this book will become an essential part of any reputable spine surgeon society's core curriculum and serve as valuable course material for continuing education programs. It is my honor to support Neuroendoscopy & Interventional Pain Medicine on behalf of the COA MISS Society.

Huilin Yang

Professor Huilin Yang

Chairman of COA MISS Society

Japanese Minimally Invasive Spine Surgery Society (JASMISS)

As JASMISS president I am interested in discussing advancements in surgical techniques, and collaborate on clinical trials. Through these initiatives, we continue to foster a collaborative environment that supports the continuous improvement and adoption of minimally invasive techniques in spine surgery.

This dedication to excellence is evident in Neuroendoscopy & Interventional Pain Medicine, which features numerous contributions from Asian authors showcasing their groundbreaking work. It is my pleasure to endorse Neuroendoscopy & Interventional Pain Medicine.

Professor Koichi Sairyo, MD, PhD

President of the Japanese Society of Minimally Invasive Spine Surgery (JASMISS)

Tokushima University, Japan.

Korean Research Society of Endoscopic Spine Surgery (KOSESS)

Founded in 2017, the Korean Research Society of Endoscopic Spine Surgery (KOSESS) aims to unite endoscopic spine surgeons in the Republic of Korea to advance the subspecialty through high-quality clinical research. This dedication to excellence is evident in Neuroendoscopy & Interventional Pain Medicine, which features numerous contributions from Korean authors showcasing their groundbreaking work.

It is my pleasure to endorse Neuroendoscopy & Interventional Pain Medicine on behalf of KOSESS.

Chang-il Ju M.D.,Ph.D.
President of KOSESS
Professor
Department of Neurosurgery
Chosun University Hospital
Gwangju, Korea
H.P. 010-3666-4100

Sociedade Brasileira de Coluna (SBC)

Founded on October 12, 1994, the Brazilian Spine Society (Sociedade Brasileira de Coluna - SBC) is a scientific, non-profit organization dedicated to advancing spine surgery through basic research and clinical studies in Orthopedics and Neurosurgery. SBC is committed to the accreditation and continued education of spine surgeons in Brazil, providing its members with access to the latest scientific evidence and technological advancements in spine care. Through its monthly publication, Columna, and various online courses, including an Introduction to Endoscopy, SBC strives to keep its members at the forefront of the field.

The editors of Neuroendoscopy & Interventional Pain Medicine have created a comprehensive reference text that is essential to SBC's core curriculum for teaching endoscopy of the spine and neuroaxis. This book presents validated clinical protocols for the endoscopic treatment of cervical and lumbar spine conditions, backed by peer-reviewed articles from its contributors.

It is my pleasure to endorse Neuroendoscopy & Interventional Pain Medicine on behalf of the Brazilian Spine Society. This work will undoubtedly play a crucial role in educating the next generation of spine surgeons in Brazil.

Dr. Robert Meves

President of SBC

Sociedad Colombiana De Cirurgia Ortopedia Y Traumatología (SCCOT)

The Sociedad Colombiana de Cirugía Ortopedia y Traumatología (SCCOT) is a non-profit, autonomous, scientific organization committed to enhancing spine care and surgery for orthopaedic and neurosurgeons, as well as other healthcare professionals in Colombia. Established to foster collaboration and innovation, SCCOT unites specialists with diverse scientific interests and expertise. Our goal is to promote continuous professional development and education, ensuring our members are well-versed in the latest advancements in spinal care.

With great enthusiasm, on behalf of SCCOT, endorse the three-volume book series Neuroendoscopy & Interventional Pain Management. This text is of significant interest to SCCOT due to its advanced technological applications and comprehensive discussion of validated clinical protocols for endoscopic spinal surgery and neuroaxis interventions.

The editors of this landmark series are esteemed leaders in minimally invasive spine surgery. Their combined expertise and dedication to advancing the field are evident throughout the volumes, making this series an invaluable resource for spine surgeons and related professionals.

Neuroendoscopy & Interventional Pain Management will serve as a cornerstone for SCCOT's continuing medical education programs. The extensive table of contents covers crucial topics related to the cervical and lumbar spine, as well as the latest technological advancements. This series will undoubtedly become a vital part of our educational initiatives, equipping our members with the knowledge and tools to excel in their practice.

I am honored to endorse this significant work on behalf of SCCOT. The dedication and expertise of the editors have produced a reference text that will shape the future of spine surgery and improve patient care worldwide.

Dr. William Arbeláez Arbeláez

President Sociedad Colombiana de Cirugía Ortopedia y Traumatología (SCCOT)

Sociedad Latinoamericana de Ortopedia y Traumatologia (SLAOT) / Latin American Society of Orthopaedics and Traumatology

The Sociedad Latinoamericana de Ortopedia y Traumatologia (SLAOT) is a non-profit, autonomous, scientific organization dedicated to orthopaedic surgeons and care professionals. SLAOT unites experts with diverse scientific interests, promoting continuous professional development and education at the highest level.

Neuroendoscopy& Interventional Pain Managementis highly relevant to SLAOT due to its exemplary use of advanced technology and detailed discussion of validated clinical endoscopic spinal surgery protocols. It is my pleasure to endorse this comprehensive text on behalf of SLAOT.

Dr. Victor Naula

President of SLAOT FEDERACION

Academia Nacional de Medicina

Av. General Justo, 365 – 7º andar - Centro - Rio de Janeiro - RJ

www.anm.org.br

Rio de Janeiro, august 22, 2024

Commendation of *Neuroendoscopy & Interventional Pain Medicine*

The Academia Nacional de Medicina de Brazil remains steadfast in its commitment to advancing medical knowledge, fostering education, and upholding the highest standards in patient care. It is with great honor that we commend Dr. Kai-Uwe Lewandrowski, one of our esteemed members, and his team of leading experts for their exemplary work in producing *Neuroendoscopy & Interventional Pain Medicine*. This timely three-volume text significantly contributes to the field of minimally invasive spinal surgery and stands as an invaluable resource for current and future spine specialists, enhancing clinical practice and improving patient outcomes.

Eliete Bouskela
Presidente

Academia
Nacional de
Medicina

Sociedad Colombiana De Columna (SOCCOL)

The Sociedad Colombiana de Columna (SOCCOL) is a non-profit, autonomous, scientific organization dedicated to advancing spine care and surgery among orthopaedic and neurosurgeons, as well as other care professionals in Colombia. Founded to foster collaboration and innovation, SOCCOL brings together experts with diverse scientific interests and backgrounds. Our mission is to promote continuous professional development and education, ensuring our members stay at the forefront of the latest advancements in spinal care.

It is with great enthusiasm that I, on behalf of SOCCOL, endorse the three-volume book series Neuroendoscopy & Interventional Pain Management. This comprehensive text is particularly significant to SOCCOL due to its exemplary use of cutting-edge technology and detailed discussion of validated clinical endoscopic surgery protocols for the spine and neuroaxis.

The editors of this landmark series are distinguished leaders in minimally invasive spine surgery. Their collective expertise and dedication to advancing the field are evident throughout the volumes, making this series an invaluable resource for spine surgeons and affiliated professionals.

Dr. Kai-Uwe Lewandrowski, a pioneer in endoscopic spine surgery, has greatly contributed to the development and refinement of minimally invasive techniques. Drs. Jorge Ramírez, Alvaro Dowling, and William Contreras, esteemed members of the Latin American spine surgery community, have played key roles in promoting these advanced surgical practices across the region. Dr. Anthony Yeung and Dr. Xifeng Zhang, world-renowned experts, have extensively published on endoscopic spine surgery and interventional pain management, further solidifying the series' credibility. Drs. Morgan Lorio and Huilin Yang are visionary minimally invasive spine surgeons who have been instrumental in prompting policy changes at national and international levels.

Neuroendoscopy & Interventional Pain Management serves as a cornerstone for SOCCOL's continuing medical education programs. The comprehensive table of contents covers topics related to the cervical and lumbar spine, as well as advanced technological applications. This series will undoubtedly become an integral part of our educational initiatives, providing our members with the knowledge and tools necessary to excel in their practice.

I am honored to endorse this significant work on behalf of SOCCOL. The dedication and expertise of the editors have resulted in a reference text that will shape the future of spine surgery and enhance the quality of care for patients worldwide.

Dr. Connie Bedoya

President of SOCIEDAD COLOMBIANA DE COLUMNA (SOCCOL)

Sociedade Brasileira de Neurocirurgia (SBN)

The Brazilian Society of Neurosurgery (SBN), established in 1957 in Brussels and affiliated with the WFNS since 1959, has been instrumental in shaping neurosurgical education and practice in Brazil. Notably, SBN was one of the first societies in the country to require examinations for the title of master, beginning in 1972. SBN continues to encourage high standards in neurosurgery through continuous education and international collaboration and is deeply involved in shaping the curriculum and standards for neurosurgical residency programs, ensuring that both fundamental and clinical research are integral parts of neurosurgical training.

In line with our commitment to excellence, I am proud to endorse Neuroendoscopy & Interventional Pain Medicine on behalf of BSN. This textbook, crafted by global leaders in minimally invasive spine surgery, serves as an invaluable resource that will enhance the education and practice of future neurosurgical specialists.

Dr. Wuilker Knoner Campos

President,

Sociedade Brasileira de Neurocirurgia

Brazilian Society of Neurosurgery (SBN)

CONTENTS

PREFACE

Direct visualization of abnormal and painful neuroanatomy has become commonplace. The endoscopic surgery technology platform has reached a level of sophistication that makes accessing anatomical compartments in the human body possible in places that hitherto have never been attempted. The intrauterine neuroendoscopy of raphe defects and their concomitant repair is one example of many that are life-changing for patients and their families.

Two developments primarily facilitated the advances. First, pioneers of the field – some of them serve as editors of this textbook – have paved the way with their unconventional approach to surgical pain care by holding their own when criticized for breaking with the traditional protocols, many of which have their foundation in image-based medical necessity criteria rather than a personalized patient-focused approach for treating abnormal or painful pathology of the spine and neuroaxis. These entrepreneur innovator surgeons have mainstreamed endoscopic spine surgery by dedicating their careers to scientific research, education, and training, ultimately leading to the establishment of treatment guidelines, updates in postgraduate surgeon training programs, and the development of credentialing standards.

Second, the technology transfers from aerospace, consumer electronics, and automotive, including automatization, robotics, navigation, artificial intelligence, 3D-printing, regenerative medicine, and above all, systems integration via miniaturization, allows surgeons to rewrite the rule book on the standard of care of many neurological and painful degenerative conditions for which historically there was not much to do because risks from exposure-related collateral damage or medical comorbidities. The ability to safely navigate towards the surgical objective and directly visualize it in great detail on a high-definition video monitor with a well-illuminated and irrigated endoscopic surgery and to intervene simultaneously with custom endoscopic instruments has broadened the indications by making surgical treatments safer and less burdensome to patients. The neuroendoscopic interventions in the brain illustrated in this text are a remarkable example of this trend.

In Neuroendoscopy and Interventional Pain Medicine Vol. 3: Interventional Pain Surgery, the editors have developed a multi-authored and clinically focused medical monograph to give the reader the most up-to-date snapshot of the current state-of-the-art endoscopic clinical practice in neurosurgery and surgical and interventional pain management. The publication is intended for physicians involved in pain management and orthopedic & neurosurgeons interested in treating common painful conditions, including degenerative disc disease, herniated discs, stenosis, peripheral nerve entrapment, tumor, and infection, with minimally invasive endoscopic techniques. A wide array of highly timely and clinically relevant topics have been assembled for this purpose. They range from suitable pain generator-based protocols, patient selection algorithms for endoscopic decompressive and reconstructive procedures, cell- and non-cell-based regenerative strategies, illustrative clinical decision-making scenarios, their respective indications, and clinical outcomes.

The chapters were selected based on contemporary trends in endoscopic surgery applications in neuro- and spinal surgery and modern interventional pain surgeries and procedures. The editors recognize that this trend is based on the need for less costly yet safe and efficient solutions for common congenital and degenerative painful neural axis and spinal conditions. Patients and other stakeholders in the ongoing debate on better value-based health care, including healthcare policymakers and payors, are demanding of surgeons less burdensome and less risky treatments with shorter time to recovery, return to work, and social reintegration. Neuroendoscopy and Interventional Pain Medicine: Vol. 3: Interventional Pain Surgery was written with these goals in mind. The editors hope the readers will find it an informative knowledge resource they will continue to revert to when implementing the endoscopy platform in their practice setting.

Kai-Uwe Lewandrowski
Center for Advanced Spine Care of Southern Arizona and Surgical Institute of Tucson
Tucson, AZ, USA

William Omar Contreras López
Clínica Foscal Internacional
Autopista Floridablanca - Girón, Km 7, Floridablanca
Santander, Colombia

Jorge Felipe Ramírez León
Fundación Universitaria Sanitas
Bogotá, D.C., Colombia

Álvaro Dowling
Orthopaedic Spine Surgeon, Director of Endoscopic Spine Clinic
Santiago, Chile

Morgan P. Lorio
Advanced Orthopedics, 499 East Central Parkway
Altamonte Springs, FL 32701, USA

Assistant Editors

Hui-lin Yang
Professor & Chairman of Orthopedic Department
The First Affiliated Hospital of Soochow University
No. 899 Pinghai Road, Suzhou, China

Xifeng Zhang
Department of Orthopedics, Wangjing Hospital
China Academy of Chinese Medical Sciences, Beijing, China

&

Anthony T. Yeung
Desert Institute for Spine Care
Phoenix, AZ, USA

List of Contributors

Alvaro Silva	Departmemt of Orthopaedics, Fundación Universitaria Sanitas, Bogotá, D.C., Colombia
Bu Rongqiang	Department of Minimally Invasive Spine Surgery, Beijing Aiyuhua Hospital, Beijing, China
Daniel Andrés Castro Prasca	Universidad del Norte, Barranquilla, Colombia
Fan Haitao	Department of Minimally Invasive Spine Surgery, Beijing Aiyuhua Hospital, Beijing, China
Guo Chaofan	Orthopedic Spine Department, Shanxi Provincial People's Hospital, Shanxi Medical University, Shanxi, China
Hyeun Sung Kim	Harrison Spinartus Hospital Chungdam, Seoul, South Korea
Il-Tae Jang	Harrison Spinartus Hospital Chungdam, Seoul, South Korea
José Antonio Name Guerra	Klinikum Bremen Mitte University of Goettingen, Bremen, Germany
Jia Kai	Orthopedic Spine Department, Shanxi Provincial People's Hospital, Shanxi Medical University, Shanxi, China
Kai-Uwe Lewandrowski	Center for Advanced Spine Care of Southern Arizona, and Surgical Institute of Tucson, Tucson, AZ, USA Departmemt of Orthopaedics, Fundación Universitaria Sanitas, Bogotá, D.C., Colombia Department of Neurosurgery in the Video-Endoscopic Postgraduate Program at the Universidade Federal do Estado do Rio de Janeiro - UNIRIO, Rio de Janeiro, Brazil
Kong Qingquan	Department of Orthopedics, West China Hospital, Sichuan University, Chengdu Sichuan, China
Li Lijun	Orthopedic Spine Department, Shaanxi Provincial People's Hospital, Shaanxi, China
Lingan Huang	Department of Sports Medicine, Beijing Key Laboratory of Sports Injuries, Peking University Third Hospital, Beijing, China
Litao Zhao	Department of Pain Medicine Center, The Central Hospital of Sanya, Sanya City. Hainan Province, China
Ma Ji	Orthopedic Spine Department, Shaanxi Provincial People's Hospital, Shaanxi, China
Marlon Sudário de Lima e Silva	CLINCOL (Endoscopic Spine Clinic), Bogotá, D.C., Colombia
Pin Feng	Department of Orthopedics, Hospital of Chengdu Office of People's Government of Tibetan Autonomous Region, ChengduSichuan, China
Pang Hung Wu	Harrison Spinartus Hospital Chungdam, Seoul, South Korea Department of Orthopaedic Surgery, Jurong Health Campus, National University Health Systems, Singapore, Singapore

Pablo Mariotti Werlang	Regina Hospital, Novo Hamburgo, Rio Grande Sur, Brazil
Radovan Sančević Žanko	Clínicas Tamanaco and Grupo Medico Santa Paula, Caracas, Venezuela
Shi Bo	Orthopedic Spine Department, Shaanxi Provincial People's Hospital, Shaanxi, China
Shu-Xun Hou	Department of Orthopedics, Chinese PLA General Hospital, Beijing, China
Thiago Soares Dos Santos	Regina Hospital, Novo Hamburgo, Rio Grande Sur, Brazil
Vincent Hagel	Asklepios Hospital Lindau, Spine Center, Lindau, Germany
William Omar Contreras López	Clínica Foscal Internacional, Autopista Floridablanca - Girón, Km 7, Floridablanca, Santander, Colombia
Wang Yu	Department of Orthopedics, West China Hospital, Sichuan University, ChengduSichuan, China
Xifeng Zhang	Department of Orthopedics, Wangjing Hospital, China Academy of Chinese Medical Sciences, Beijing, China
Xueqin Rong	Department of Pain Medicine Center, The Central Hospital of Sanya, Sanya City. Hainan Province, China
Yan Yuqiu	Department of Minimally Invasive Spine Surgery, Beijing Aiyuhua Hospital, Beijing, China
Zhang Bin	Department of Orthopedics, Hospital of Chengdu Office of People's Government of Tibetan Autonomous Region, ChengduSichuan, China
Zhen-Zhou Li	Department of Orthopedics, Chinese PLA General Hospital, Beijing, China
Zhang Jiajing	Department of Minimally Invasive Spine Surgery, Beijing Aiyuhua Hospital, Beijing, China
Zeng Qingquan	Department of Minimally Invasive Spine Surgery, Beijing Aiyuhua Hospital, Beijing, China

CHAPTER 1

Interlaminar Lumbar Endoscopy

José Antonio Name Guerra[1], **Daniel Andrés Castro Prasca**[2], **William Omar Contreras López**[3,*] and **Kai-Uwe Lewandrowski**[4,5,6]

[1] *Klinikum Bremen Mitte University of Goettingen, Bremen, Germany*

[2] *Universidad del Norte, Barranquilla, Colombia*

[3] *Clínica Foscal Internacional, Autopista Floridablanca - Girón, Km 7, Floridablanca, Santander, Colombia*

[4] *Center for Advanced Spine Care of Southern Arizona, and Surgical Institute of Tucson, Tucson, AZ, USA*

[5] *Departmemt of Orthopaedics, Fundación Universitaria Sanitas, Bogotá, D.C., Colombia*

[6] *Department of Neurosurgery in the Video-Endoscopic Postgraduate Program at the Universidade Federal do Estado do Rio de Janeiro - UNIRIO, Rio de Janeiro, Brazil*

Abstract: This chapter provides a comprehensive overview and technique guide for endoscopic interlaminar lumbar decompression surgery, a minimally invasive surgical technique for managing herniated discs and spinal stenosis. The authors discuss the relevant surgical anatomy of the lumbar spine, the inclusion and exclusion criteria for the surgery, and explain the surgery's step-by-step choreography by highlighting the use of advanced imaging and endoscopic technology. The authors review their clinical outcomes and discuss common complications and their management. They highlight the limitations of the procedure. This book chapter is a valuable resource for surgeons and healthcare professionals interested in understanding and implementing endoscopic lumbar interlaminar decompression as an effective and minimally invasive approach for managing sciatica-type low back and leg pain.

Keywords: Interlaminar endoscopy, Herniated disc, Spinal stenosis, Sciatica-type low back and leg pain.

INTRODUCTION

One of the most frequent causes of low back pain is disc pathology, which is painful due to irritation or compression of the surrounding neural structures [1]. Disc pathology can occur in isolation or in combination with spinal canal stenosis, reflecting mixed symptoms, including mechanical pain, neurogenic claudication,

* **Corresponding author William Omar Contreras López:** Clínica Foscal Internacional, Autopista Floridablanca - Girón, Km 7, Floridablanca, Santander, Colombia; Tel: +3116659964; E-mail: josename@hotmail.com; Home Page: www.doctorname.co

Kai-Uwe Lewandrowski & William Omar Contreras López (Eds.)

and signs of root stretching [2 - 6]. The surgical treatment of this type of entity has evolved from open procedures, becoming less and less invasive today, as is the case of the uniportal interlaminar percutaneous endoscopic approach [7 - 33]. Its efficacy, safety, and cost-effectiveness have been widely described in the literature, highlighting shorter surgical time, less postoperative pain, less intraoperative bleeding, less perioperative infection, minimal incisions, continuous irrigation, and absence of retractor systems; consolidating itself as an ambulatory surgical strategy [34].

Progress in the advancement of percutaneous techniques has brought the development of increasingly specialized endoscopes and endoscopic instruments, thus expanding the spectrum of spinal pathologies treatable by this route. Today, it is possible to perform discectomy and spinal canal decompression with the "over the top" technique through the interlaminar approach [35]. In the case of discectomy, the endoscopes used are usually long and thin with 4.1 mm working channels to allow delicate retraction of neural structures. In contrast, endoscopes for stenosis are shorter and thicker, with 5.6 mm working channels, and allow the use of more robust instruments such as burs and shavers of different sizes [36]. With the development of the interlaminar approach and improved endoscopic optics and instrumentation, endoscopic spine surgery is applied to a broad spectrum of degenerative lumbar diseases [28 - 30, 37].

Advantages

Interlaminar endoscopy offers several advantages in minimally invasive spine surgery. Firstly, it affords direct visualization and enhanced magnification and illumination. Additionally, this technique preserves the integrity of the surrounding muscles and ligaments, promoting faster recovery and reducing the risk of complications. Its specific advantages are:

1. Better exposure of the lumbar spinal microanatomy through a single 8-mm access port.
2. Minimal trauma to the paraspinal muscles on the ipsilateral side, and sparing of the paraspinal muscles on the contralateral side [8].
3. Sufficient osteoligamentous decompression, preserving the stabilizing anatomy [9].
4. Access to disc pathology with minimal manipulation of the neural structures and a lower rate of neurological injury.
5. Faster postoperative recovery and rehabilitation, and minimal lower back pain at long-term follow-up [33].
6. Cost-effectiveness due to surgical times being comparable to or shorter than other techniques, allowing for outpatient surgical management [33].

7. Lower incidence of infection, bleeding, and lumbar spine instability [38].

Indications

Interlaminar spinal endoscopy is indicated in lumbar disc herniation that causes unrelenting pain that is unresponsive to conservative care. This technique is also beneficial for managing spinal stenosis, particularly in the central canal. Its translaminar surgical access corridor to the spinal canal makes this minimally invasive technique a versatile option for a range of painful spinal pathologies, offering patients a faster recovery and improved quality of life. The authors consider the following to be acceptable indications for interlaminar lumbar endoscopy [15]:

1. Intervertebral disc herniations causing unrelenting pain.
2. Cranial or caudal far-migrated disc herniations.
3. Stenosis of the central spinal canal and lateral recess.
4. Combined central and paracentral disc herniation with facet hypertrophy and hypertrophy of the ligamentum flavum.
5. Other pathologies that compress the spinal cord or spinal roots including:
   a. Cyst of the facet joint
   b. Cyst of the yellow ligament
   c. Ossification of the yellow ligament
   d. Foraminal stenosis

Contraindications

There are specific contraindications to consider when employing the interlaminar spinal endoscopy technique. It may not be suitable for patients with severe spinal instability, as the procedure involves accessing the spinal canal through the interlaminar space. Individuals with active infections, significant spinal deformities, and prior spinal surgery that has resulted in extensive scar tissue formation may also be unsuitable for the interlaminar technique. There may be some relative contraindications that vary from surgeon to surgeon based on skill level and experience; however, the authors consider the following to be absolute contraindications to the interlaminar endoscopy:

1. Segmental instability evident on dynamic radiographs
2. Grade 2 or higher spondylolisthesis according to the Meyerding criteria [39]
3. Severe degenerative scoliosis
4. Infection
5. Malignancy

CHAPTER 2

Comprehensive Introduction to Endoscopic Transforaminal Lumbar Discectomy With Trephines

Radovan Sančević Žanko[1,*]

[1] *Clínicas Tamanaco and Grupo Medico Santa Paula, Caracas, Venezuela*

Abstract: Endoscopic transforaminal lumbar discectomy (ETLD) with trephines represents a minimally invasive surgical procedure for treating lumbar disc herniation. This technique best suits the novice surgeon and offers several advantages over traditional open surgery, including reduced tissue trauma, faster recovery, and improved patient outcomes. It simplifies the placement of the endoscopic working cannula by creating an initial working space under fluoroscopic guidance without the need for an initial foraminoplasty. This chapter delves into the technical and procedural aspects of ETLD with trephines, providing a detailed overview of the procedure, its indications, contraindications, surgical steps, and potential complications. Furthermore, we highlight the advantages and limitations of this innovative technique and discuss its established role in spinal surgery.

Keywords: Endoscopic lumbar discectomy, Foraminoplasty, Herniated disc, Trephines.

INTRODUCTION

Lumbar disc herniations are common in adults and are more relevant in any spine surgeon's practice [1 - 4]. The aging population demographic dynamic has shifted the focus of spinal endoscopy from just treating disc herniations to broadening the indication of spinal stenosis, as the two conditions often coincide with the same patient and sometimes even at the same surgical level [5 - 7]. This degenerative disease process results in the progressive vertical collapse of the spinal motion segment that leads to significant back pain, radiculopathy, and functional disability. While open surgical techniques have long been the gold standard for treatment, they are associated with substantial tissue trauma, postoperative pain,

* **Corresponding autor Radovan Sančević Žanko:** Clínicas Tamanaco and Grupo Medico Santa Paula, Caracas, Venezuela; E-mail: radosancevic@gmail.com

and extended recovery times [8]. The advent of endoscopic procedures revolutionized the field of spinal surgery, and ETLD has emerged as an up-and-coming minimally invasive alternative.

Earlier versions of the transforaminal decompression procedure involved trephines placed over a guidewire and dilators into the surgical neuroforamen [9]. Sequentially larger trephines are introduced to create a working space. These steps are typically done under fluoroscopic guidance and make an initial working space in the lateral aspect of the facet joint complex at the surgical level. This step dramatically simplifies the placement of the working cannula since no extensive foraminoplasty is required. While the experienced endoscopic spinal surgeon may prefer to perform these initial steps under direct visualization [10], the novice may find placing the endoscopic working cannula under fluoroscopic guidance easier as it simplifies the first few procedural steps quite a bit [11, 12].

In this chapter, the authors give the reader a procedural overview of the endoscopic transforaminal lumbar discectomy with trephines which involves accessing the herniated disc through a small incision near the affected vertebral level with the aid of a tubular retractor system, specialized endoscopic instruments, and real-time imaging guidance, the surgeon navigates through the intervertebral foramen, reaching the herniated disc. Trephines, cylindrical surgical instruments, are then used to remove a targeted portion of the herniated disc material, decompressing the affected nerve root and alleviating the associated symptoms.

Indications and Contraindications

1) Indications: ETLD with trephines is suitable for patients with symptomatic lumbar disc herniation causing radicular pain, sciatica, or neurological deficits. Typical indications include but are not limited to persistent pain despite conservative treatment, neurological deficits, severe radiculopathy, and a herniated disc confirmed by imaging studies [13 - 18].

2) Contraindications: Certain patient characteristics and anatomical factors may contraindicate ETLD with trephines. These include significant instability of the affected vertebral segment, sizeable central disc herniation compressing the spinal canal, prior lumbar surgery, active infection, and severe spinal stenosis [16 - 18].

Advantages and limitations

1) Advantages: ETLD with trephines offers several advantages over open surgical techniques. These include minimal tissue trauma, reduced blood loss, shorter operative time, preservation of anatomical structures, faster recovery, reduced

postoperative pain, decreased hospital stay, and potential cost savings. The procedure's minimally invasive nature also allows for outpatient or short-stay hospitalization, further improving patient satisfaction.

2) Limitations: While ETLD with trephines is generally safe and effective, it has limitations such as challenges such as limited access to the central disc or contralateral foramen, the learning curve for surgeons, the need for specialized training, and the potential for recurrent disc herniation, dural tears, nerve root injury, dysesthesia, bleeding, and transient or persistent neurological deficits and in rare cases require careful consideration.

Transforaminal Outside-in Technique

The transforaminal outside-in endoscopic lumbar technique combines the benefits of easy transforaminal access to the neuroforamen and spinal canal with direct endoscopic visualization, allowing for precise diagnosis and targeted treatment of the painful lumbar pathology [19 - 24]. The target area is accessed by placing the endoscopic work cannula, typically measuring 8.9 mm in diameter the intervertebral foramen – an existing anatomical structure – to treat herniated discs or foraminal stenosis, with minimal disruption to surrounding tissues by maneuvering within the epidural space, in Kambin's triangle [25, 26]; a working space between the traversing and exiting nerve root and the inferior pedicle. Most importantly, the transforaminal technique requires less bony resection typically needed in a translaminar procedure and therefore has a lower incidence of iatrogenic instability (Fig. **1**).

This technique offers an effective solution for relieving nerve root compression and associated radiculopathy by directly visualizing and decompressing the foraminal space [27 - 30]. Briefly, the method involves placing a working channel over sequential dilators. The endoscopic working channel is a tubular retractor enabling the insertion of an endoscope and specialized instruments. The working channel may have various tip configurations to facilitate specific procedural steps and objectives, such as safe retraction of the exiting nerve root. In real-time visualization, the surgeon can navigate through the foraminal and epidural space, accurately identify the painful pathology, and perform precise decompression, ablation, or discectomy procedure. In doing so, the surgeon can address foraminal stenosis affecting the exiting nerve root [31] (Figs. **2**-**6**).

CHAPTER 3

Classification of Lateral Region of Lumbar Spinal Canal and the Choice of Endoscopic Approach

Kong Qingquan[1,*] and **Wang Yu**[1]

[1] *Department of Orthopedics, West China Hospital, Sichuan University, ChengduSichuan, China*

Abstract: Degenerative lateral lumbar spinal canal stenosis commonly affects the elderly, leading to significant morbidity. This chapter aims to introduce a novel categorization for the lateral compartments of the lumbar spine and to assess the effectiveness of surgical interventions for this condition. A new anatomical classification has been established, partitioning the area into five distinct zones. To ascertain the consistency of this nomenclature, lumbar scans from thirty individuals with single-zone afflictions at our facility were reviewed by a trio of evaluators. Following this, we conducted a prospective study tracking the surgical results in 76 subjects with single-zone lateral lumbar canal narrowing over two years. These individuals were treated using either percutaneous endoscopic transforaminal or interlaminar decompression techniques, chosen based on the newly developed zonal system. Outcomes were evaluated using the Macnab criteria, and changes in leg pain were measured with the visual analog scale (VAS) before and after surgery. During the study employing our categorization, the average observation period was 15.6 months. By the final evaluation, 93.4% of the cases were rated as good or excellent. The average initial VAS score of 5.72 significantly improved to 1.26 within three months after surgery and further to 0.78 by the final assessment. Notably, two individuals experienced dural tears, and one had postoperative bone fragment migration into the vertebral canal. The findings suggest that this innovative lateral lumbar canal classification facilitates precise surgical planning, contributing to the high rate of satisfactory results following endoscopic procedures.

Keywords: Classification, Endoscopic foraminoplasty, Lateral canal stenosis.

INTRODUCTION

The anatomical area of lumbar spinal stenosis (LSS) encompasses several regions including the central canal, lateral recess, and neural foramina, or their various combinations. Diverse interpretations exist for narrowing within the spinal canal's

* **Corresponding author Kong Qingquan:** Department of Orthopedics, West China Hospital, Sichuan University, ChengduSichuan, China; E-mail: kqqspine@126.com

lateral zone, identified in the literature as the radicular canal, lateral recess zone, or nerve root canal [1 - 3]. Historically, the "radicular canal" designation was first applied to describe this lateral space [1, 3, 4]. The precise anatomical borders of this lateral area are influenced by the variability in the exit points of spinal nerve roots across the lumbar segments, a factor that complicates the precise localization of each nerve root's emergence through standard imaging techniques. Pioneering efforts by Schlesinger and Epstein in 1955 and 1972 highlighted clinical and imaging presentations of facet syndrome in a series of case reports [5, 6]. Subsequent to their work, numerous scholars have acknowledged and further elaborated on the concept of the "lateral recess" [2, 6, 7]. Nevertheless, there remains an ongoing debate regarding its definitive anatomical delimitations [1, 3 - 5, 7 - 9].

The use of clinical spinal endoscopy has evolved from addressing soft disc herniation to encompassing the broader scope of lumbar spinal stenosis. Positive outcomes from percutaneous endoscopic lumbar decompression (PELD) for lateral lumbar stenosis have been documented, with success rates ranging from 82% to 92% [10]. Despite these advancements, a detailed classification system for the lateral aspects of the spinal canal, which would guide endoscopic surgeons in selecting the optimal surgical approach for specific pathologies, is lacking. To fill this gap, the authors of this chapter propose the sub-classification of the lateral lumbar spinal canal (LLSC) and segment this area into five distinct zones, each characterized by unique anatomical landmarks.

Lateral Canal Classification

In this work, the authors introduce a novel five-zone framework for anatomical categorization of the lateral lumbar spinal canal (LLSC), integrating considerations of the nerve root trajectory as well as the biomechanical and pathological attributes specific to each zone. The delineation commences at the medial pedicular line and the midline of the spinous processes, segmenting the LLSC laterally into five distinct areas. Comprehensive descriptions of the demarcations for each zone are consolidated within Table **1**, with visual representations provided in Figs. (**1** and **2**). The zones are characterized as follows:

Retrodiscal Space (Zone 1)

Lee C.K [2] originally defined the entrance zone, which in the context of this text is synonymous with the retrodiscal space, located at the uppermost portion of the lateral canal. This region's height aligns with that of the intervertebral disc, bordered by the disc itself, the superior articular process (SAP), the joint capsule, and the ligamentum flavum. T2-weighted MRI images, both parasagittal and axial, are crucial for identifying stenosis within this area, as disc herniation and enlargement of the ligamentum flavum are primary contributors to compression. The depiction of intervertebral discs in axial MRI or CT scans is indicative of this specific zone.

Table 1. Boundary definitions of each Zone.

-	Superior Border	Inferior Border	Medial Border	Lateral Border	Ventral Adjacent	Dorsal Adjacent
Zone 1	Inferior edge of the rostral vertebral body	Superior edge of the vertebral body	The midline of the medial pedicular line and spinous process line(open to the central canal)	The medial pedicular line (open to intervertebral foramen)	The posterolateral surface of the disc	Superior articular process (SAP)
Zone 2	Superior edge of the vertebral body	Horizontal mid pedicular line	Same as above	Same as above (adjoin to the medial surface of the pedicles)	Posterior surface of the vertebral body	Facet joint, lateral part of the lamina and attached ligamentum flavum
Zone 3	Horizontal mid pedicular line	Horizontal inferior pedicular line	Same as above	Same as above	Same as above	The anterior surface of the lamina
Zone 4	Horizontal inferior pedicular line	Inferior edge of the vertebral body	Same as above	Same as above(open to intervertebral foramen)	Same as above	Pars interarticularis/lamina
Zone 5	Inferior margin of the pedicle	Superior margin of the adjacent pedicle	Medial pedicular line (open to central canal)	Lateral pedicular line	The disc and posterior margin of the two adjacent vertebral bodies	The lateral aspect of the facet joint

Upper Bony Lateral Recess (Zone 2)

The osseous component of the lateral spinal canal bifurcates into a superior segment, which lies anterior to the facet joint, flanked by the lateral edge of the lamina and the contiguous ligamentum flavum. This constricted area is encapsulated by skeletal elements, specifically the vertebral body at the front and

CHAPTER 4

Percutaneous Endoscopic Decompression Through Bilateral Transforaminal Approach For Lumbar Central Canal Stenosis

Kong Qingquan[1,*], **Zhang Bin**[2] and **Pin Feng**[2]

[1] *Department of Orthopedics, West China Hospital, Sichuan University, ChengduSichuan, China*

[2] *Department of Orthopedics, Hospital of Chengdu Office of People's Government of Tibetan Autonomous Region, ChengduSichuan, China*

Abstract: Endoscopic techniques have garnered positive outcomes in treating lumbar spinal stenosis, with percutaneous endoscopic transforaminal decompression showing particular efficacy for addressing stenosis in the intervertebral foramen and lateral recess. However, the use of transforaminal decompression for central lumbar spinal stenosis (CLSS) is often met with skepticism. In this section, the authors share insights from their practice alongside data from a sequential observational study involving 47 CLSS patients treated *via* a bilateral transforaminal endoscopic approach. Clinical metrics such as the Oswestry Disability Index (ODI), VAS scores for back and leg pain, and the Macnab criteria were employed to measure the outcomes. The radiographic analysis involved comparing the lumbar dural sac's cross-sectional area before and after the procedure. The findings indicate substantial clinical improvement and a notable expansion of the dural sac's cross-sectional area at the final follow-up. There were no reported cases of infection, wound complications, or need for subsequent surgery. Thus, barring principal pathologies located dorsally to the dural sac, the bilateral transforaminal endoscopic approach is advocated as an adequate, reliable, and minimally invasive option for CLSS management.

Keywords: Central Lumbar Spinal Stenosis, Foraminoplasty, Minimally invasive treatment, Percutaneous endoscopic lumbar decompression.

INTRODUCTION

Central lumbar spinal stenosis (CLSS), a condition predominantly seen in individuals over the age of 60, is characterized by a gradual degenerative process. Arthritic changes in facet joints, thickening and calcification of ligaments, and disc protrusions are common etiologies that impair the quality of life and can lead

[*] **Corresponding autor Kong Qingquan:** Department of Orthopedics, West China Hospital, Sichuan University, ChengduSichuan, China; E-mail: kqqspine@126.com

Kai-Uwe Lewandrowski & William Omar Contreras López (Eds.)

to escalating disability [1, 2]. The hallmark symptom of CLSS, neurogenic claudication, intensifies with standing or walking and is alleviated by reclining or flexing the spine. Additional manifestations may include a sensation of tingling, numbness, and muscular weakness in the legs [2 - 4].

Initial management strategies for CLSS typically involve non-surgical interventions such as physical therapy, structured exercise, pain relief medications, and epidural injections [5, 6]. Should these measures prove ineffective, surgical decompression becomes a viable option [7, 8]. Surgical approaches for CLSS often entail relieving pressure on neural elements, optionally accompanied by spinal fusion [9]. Traditional laminectomy, which involves removing posterior spinal elements like the lamina and ligamentum flavum, has been a standard decompressive technique but is sometimes associated with chronic back pain or iatrogenic instability, potentially leading to revision surgeries [11, 12]. In contrast, minimally invasive surgery (MIS), including micro-endoscopic decompression (MED), has been gaining traction for CLSS treatment, offering benefits over conventional laminectomy in some studies [11, 13].

As MIS has advanced, percutaneous endoscopic methods have demonstrated effective outcomes for disc issues in the cervical and lumbar spine. These techniques have also been adapted for CLSS, with bilateral decompression *via* a unilateral interlaminar approach recognized as straightforward, safe, and efficacious [14 - 16]. Percutaneous endoscopic transforaminal decompression (PETD) has shown efficacy for stenosis in the intervertebral foramen and lateral recess, though it has received some skepticism when applied to CLSS [17 - 20]. Reports in the literature on PETD for CLSS remain sparse. In this discussion, the authors describe performing bilateral spinal decompression for CLSS using a percutaneous endoscopic bilateral transforaminal technique. The objective is to appraise the results and ascertain the effectiveness of this method in managing CLSS.

Clinical Presentation

In contrast to the congenital etiologies of degenerative lumbar spinal stenosis, degenerative CLSS typically stems from an overgrowth of facet joints, thickening and hardening of the ligamentum flavum, and protrusion of intervertebral discs [1 - 4, 25, 26]. Compression on the posterior aspect of the dural sac is often not critical, and imaging may still show the presence of adipose tissue on the posterior dural sac in severe cases of CLSS, as depicted in axial MRI scans (Fig. **1**). Beyond the changes occurring dorsally to the dural sac, like the ligamentum flavum's ossification, the predominant issue in degenerative CLSS is the reduction in the central spinal canal's transverse diameter. The dural sac's sac-like nature means that lateral constriction of the spinal canal diminishes its overall volume. Degenerative processes typically induce constriction of the lateral recesses initially, which then exacerbates, culminating in central spinal canal stenosis. Due to the dural sac's capacity to distend, the central cauda equina has a degree of mobility. However, the nerve structures within the lateral recesses are confined and thus more susceptible to symptomatic compression. Given that the sources of compression are usually lateral to the dural sac and nerve impingement occurs predominantly in the lateral recesses, addressing degenerative CLSS with a transforaminal approach is a practical strategy.

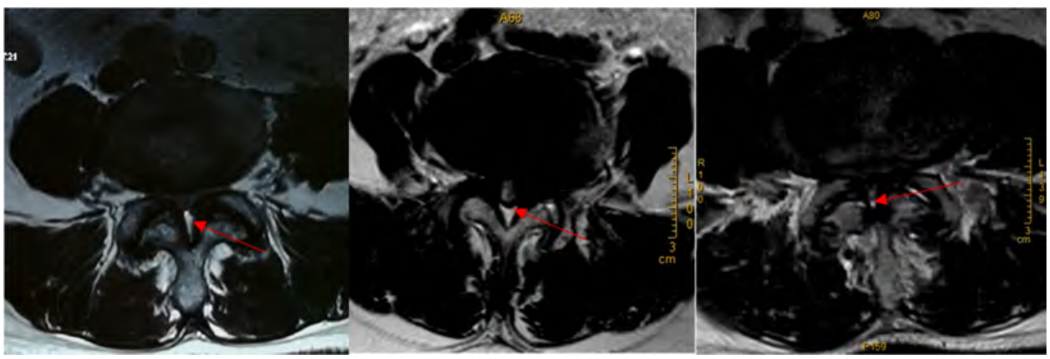

Fig. (1). In cases of advanced lumbar spinal stenosis, MRI scans often reveal the persistence of adipose tissue located dorsally to the dural sac (indicated by a red arrow pointing to the adipose tissue in the images). The principal contributors to the narrowing are typically compressive forces originating from both the left and right sides, as well as from the front.

The central aim of surgical intervention for central lumbar spinal stenosis (CLSS) is to achieve thorough decompression while minimizing surgical trauma and the risk of postoperative complications [2, 3, 9]. Advances in minimally invasive spine surgery (MISS) have considerably decreased the physical impact of surgery and lessened the frequency of post-surgical lumbar fusion. Techniques like micro-endoscopic decompression (MED) that facilitate unilateral laminectomy for bilateral decompression offer marked improvements over classical laminectomy methods [11, 13]. However, these techniques are not without their drawbacks, such as inevitable disruption to muscle structures and challenges in achieving full decompression on the contralateral side [27].

The unilateral interlaminar approach for endoscopic bilateral decompression has been recognized for its minimal invasiveness, reduced bleeding, and preservation of ligamentous and joint integrity. Percutaneous endoscopic interlaminar decompression (PEID) has been employed by various experts for treating CLSS, with commendable outcomes reported in scholarly works, making it a notable

CHAPTER 5

Endoscopically Visualized Rhizotomy for the Management of Chronic Facetogenic Low Back Pain

José Antonio Name Guerra[1], **Daniel Andres Castro Prasca**[2], **William Omar Contreras López**[3,*] and **Kai-Uwe Lewandrowski**[4,5,6]

[1] *Medico Neurocirujano, Universidad del Norte, Universidad de Göttingen Cr. 30 Corredor universitario # 1 - 850, Unidad Médica Portoazul, Consultorio 520, Barranquilla, Colombia*

[2] *Universidad del Norte, Barranquilla, Colombia*

[3] *Clínica Foscal Internacional, Autopista Floridablanca - Girón, Km 7, Floridablanca, Santander, Colombia*

[4] *Center for Advanced Spine Care of Southern Arizona and Surgical Institute of Tucson, Tucson, AZ, USA*

[5] *Departmemt of Orthopaedics, Fundación Universitaria Sanitas, Bogotá, D.C., Colombia*

[6] *Department of Neurosurgery in the Video-Endoscopic Postgraduate Program at the Universidade Federal do Estado do Rio de Janeiro - UNIRIO, Rio de Janeiro, Brazil*

Abstract: This chapter provides a comprehensive overview of endoscopic lumbar facet rhizotomy, a minimally invasive surgical technique for managing chronic low back pain originating from the facet joints. The authors discuss the relevant anatomy of the lumbar facet joint complex, the pathophysiology of facet joint-related pain, the inclusion and exclusion criteria for the surgery, and explain the surgery's step-by-step choreography by highlighting the use of advanced imaging and endoscopic technology for precise targeting and ablation of the medial branch of the dorsal facet nerve. The authors review their clinical outcomes. Furthermore, the authors discuss the current evidence, research advancements, and future directions in the field. This book chapter is a valuable resource for surgeons, pain specialists, and healthcare professionals interested in understanding and implementing endoscopic lumbar facet rhizotomy as an effective and minimally invasive approach for managing facet joint-related low back pain.

Keywords: Endoscopic lumbar facet rhizotomy, Facet joints, Minimally invasive surgical technique, Advanced imaging, Pain specialists.

* **Corresponding author William Omar Contreas López:** Clínica Foscal Internacional, Autopista Floridablanca - Girón, Km 7, Floridablanca, Santander, Colombia; E-mail: wyllcon@gmail.com

Kai-Uwe Lewandrowski & William Omar Contreras López (Eds.)

INTRODUCTION

Low back pain is a principal condition worldwide, burdening the public health systems, with a lifetime prevalence reaching 84% [1]. This high disease burden underscores the significance of this issue for healthcare policies and medical care funding. The condition is closely associated with depression, work disability, immobilization, reduced functionality, and limitations in daily activities. Not only does it cause individual suffering, but it also carries substantial social and economic implications [2]. Chronic low back pain can have various causes, including dysfunction or structural abnormalities in different anatomical structures such as the lumbar intervertebral discs, nerve roots, fascia, spinal ligaments, osteophytes, and muscles (misreported quantity and quality of lumbar paracentral muscles according to Goutallier's classification) [3]. However, in most cases, pain is attributed to the degeneration of the lumbar facet joints (zygoapophyseal joints), accounting for 15% to 45% of individuals with chronic low back pain. The symptoms are predominantly localized in the axial region, although some patients may develop radicular pain without evidence of spinal root compression on imaging (as seen in herniated discs). Symptoms are aggravated primarily by axial movements [4, 5].

Managing chronic low back pain from facet joint degeneration follows an incremental approach (Fig. **1**). Typically, it begins with conservative measures, including pharmacological treatment and lifestyle modifications. Physical therapies are also utilized. If pain relief is not achieved, periarticular facet joint injections with long-acting steroids and local anesthetics may be recommended for diagnostic and therapeutic purposes. However, the effectiveness of the latter remains uncertain [6]. In cases where patients experience temporary pain relief following facet joint injections but subsequently experience recurrence, percutaneous radiofrequency ablation of the medial dorsal branch of the facet joint becomes an option.

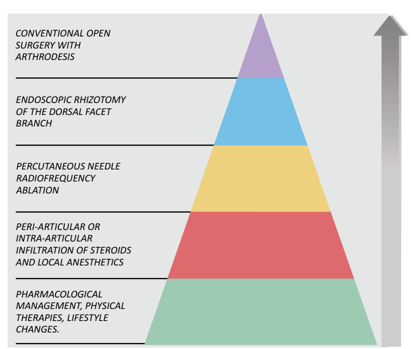

Fig. (1). Pyramid of the different phases of axial low back pain management.

This procedure has shown a high success rate in pain management [7]. Fluoroscopy-guided radiofrequency denervation of the medial branch offers longer-lasting effects than the previously mentioned treatment options. However, due to anatomical variations and changes in the path of the dorsal facet ramus, extensive ablation is often required to achieve satisfactory pain relief. Therefore, a novel technique known as endoscopic rhizotomy of the dorsal facet branch has been described [8 - 15]. Endoscopic rhizotomy (ER) and the different endoscopic decompression procedures of the spine are novel techniques corresponding to the evolution of percutaneous radiofrequency ablation. This technique has the same objective on the dorsal facet branch. However, being endoscopic, it guarantees direct visualization of the anatomical structures, allowing easy detection of the nerve to be intervened, which leads to stable and lasting pain relief due to the most complete and extensive denervation of the branch [16].

Relevant Anatomy

The lumbar facet joint complex comprises paired joints located at the posterior aspect of the lumbar vertebrae. These joints, also known as zygoapophyseal joints, are crucial in providing stability and facilitating the controlled movement of the lumbar spine. Each facet joint consists of a superior and inferior articular process that interlocks with the corresponding processes of adjacent vertebrae. The joint surfaces are covered with hyaline cartilage, allowing smooth gliding and reducing friction during movement.

Ligaments, such as the capsular and ligamentum flavum, surround and reinforce the facet joints, providing additional stability. The medial branches of the primary dorsal ramus of the spinal nerves provide innervation of the facet joints, which transmit sensory information, including pain signals, from the facet joint complex.

Understanding the anatomy of the lumbar facet joint complex is essential for diagnosing and treating conditions that affect these joints, such as facet joint arthritis or facet joint-related back pain. Some authors suggested anatomical caveats based on their clinical experience with the surgical rhizotomy procedure [17]:

1. The medial branch nerve is (in most cases) in the groove on the side of the superior articular process (ascending facet) that intersects with the transverse process (curvature) (Fig. **2**).
2. The nerve may be covered by a fibro-osseous ligament, requiring more effective ablation than conventional radiofrequency techniques (Fig. **2**).
3. Each articular facet is innervated by the medial branch of two adjacent dorsal rami that run closely on the lateral border of the superior articular process of

CHAPTER 6

Percutaneous Lumbar Facet Rhizolysis with Radiofrequency

Radovan Sančević Žanko[1,*], **Alvaro Silva**[2] and **Kai-Uwe Lewandrowski**[2,3,4]

[1] *Neurosurgeon, minimal invasive spinal surgeon, Instituto de Clínicas Tamanaco and Grupo Medico Santa Paula, Caracas, Venezuela*

[2] *Departmemt of Orthopaedics, Fundación Universitaria Sanitas, Bogotá, D.C., Colombia*

[3] *Center for Advanced Spine Care of Southern Arizona and Surgical Institute of Tucson, Tucson, AZ, USA*

[4] *Department of Neurosurgery in the Video-Endoscopic Postgraduate Program at the Universidade Federal do Estado do Rio de Janeiro - UNIRIO, Rio de Janeiro, Brazil*

Abstract: Chronic low back pain (CLBP) is highly prevalent and may be caused by arthritic changes in the lumbar facet joints. Percutaneous lumbar facet rhizolysis with radiofrequency (RF) has emerged as a minimally invasive procedure for the management of CLBP originating from the lumbar facet joints by selectively disrupting the medial and lateral branches of the dorsal branch of the sinuvertebral nerves transmitting pain signals from the facet joints to the nervous system. The authors employ a modern RF probe inserted percutaneously near the affected facet joint during the fluoroscopically guided procedure. Once the cannula is positioned correctly, RF energy is delivered, generating localized heat and creating a thermal lesion on the medial branch nerves supplying the facet joint. This selective thermal lesioning disrupts the pain transmission pathway without affecting motor function, thus providing pain relief for an extended period. The RF technology employed by the authors is based on Elliquence low-frequency technology and is known to cause little tissue damage beyond the target area. The authors present the clinical results with their extended clinical cohort. This procedure can be performed outpatient, requiring minimal sedation and quicker recovery than traditional surgical approaches. This chapter aims to illustrate the efficacy of percutaneous lumbar facet rhizolysis with the Elliquence RF Dart probe in the management of CLBP by comparatively analyzing the existing clinical evidence regarding long-lasting pain reduction, improved function, and overall patient satisfaction.

Keywords: Percutaneous, Lumbar facet, Rhizolysis, Chronic low back pain, Pain management strategies.

[*] **Corresponding author Radovan Sančević Žanko:** Clínicas Tamanaco and Grupo Medico Santa Paula, Caracas, Venezuela; E-mail: radosancevic@gmail.com

Kai-Uwe Lewandrowski & William Omar Contreras López (Eds.)

INTRODUCTION

Facet-related low back pain is a common and challenging condition that affects many individuals worldwide [1]. The facet joints, also known as zygapophyseal joints, are small synovial joints in the posterior spinal column. These joints are crucial in providing stability and enabling smooth spine movement. However, when these facet joints become a source of pain, it can lead to chronic low back pain and functional limitations. Facet-related low back pain can arise from various factors, including degenerative changes, injury, inflammation, or mechanical stress on the facet joints. The pain typically manifests as localized discomfort in the lower back region, often accompanied by stiffness, reduced range of motion, and occasional radiation into the buttocks or thighs. The intensity of facet-related pain can vary, ranging from mild to debilitating, significantly impacting an individual's daily activities, work productivity, and quality of life.

Diagnosing facet-related low back pain may not be straightforward, as its symptoms can overlap with those of degenerative disc disease [2, 3]. The correct diagnosis is best made with a comprehensive approach that includes a thorough medical history review, physical examination, and diagnostic imaging, such as X-rays, MRI scans, or diagnostic injections, to identify the facet joints as the pain generator accurately. Treatment options range from conservative measures to more invasive interventions, depending on the severity and duration of symptoms. Non-surgical approaches may include physical therapy, anti-inflammatory medications, exercise programs, and assistive devices for pain management [4]. Many patients have associated painful facet cysts [5, 6]. However, in cases where conservative methods fail to provide adequate relief, interventional procedures such as facet joint injections or radiofrequency rhizotomy may be considered to directly target and alleviate the pain originating from the facet joints.

In this chapter, the authors give the reader a procedural overview of the modern radiofrequency facet de-innervation commonly known as facet rhizolysis.

Tissue Ablation Technology

Modern electrosurgery can be traced back to the development of Doyen's machines in the 1920s and Bovie machines in the 1930s. Electrosurgical units typically operate within the frequency range of 200 to 500 kHz. When these devices operate within this frequency range, the electrode that comes into contact with the tissue becomes heated, effectively acting as a cautery instrument. In the 1950s, Malis introduced a spark gap machine consisting of a bipolar generator and forceps designed to control the lateral spread of heat to adjacent tissues. High-frequency (HF) surgery and spinal endoscopy are complementary procedures for treating herniated discs. Galvanosurgery and diathermy surgery, which originated in the mid-19th century, are precursors to modern HF treatments. In the early 20th century, Erbe developed HF surgical devices in Europe, while Bovie did so in the USA. Endoscopic visualization devices and high-frequency surgical devices are now prevalent in operating theaters worldwide, being utilized across various surgical disciplines in both hospital and ambulatory settings. High-frequency surgery involves passing HF alternating current through the human body to achieve targeted hemostasis and tissue severance through the heat generated, particularly in monopolar applications.

HF electrosurgery typically employs generators with a maximum power of 400 Watts. The output voltage of these generators can reach up to 4 kilovolts (kV) when not actively in use. Weaker devices with maximum outputs of 50 Watts and lower voltages are commonly used in dentistry and ophthalmology. Generators available in the market often offer different operating modes, including cutting and coagulation. The key distinction lies in the creation of arcs, which possess a cutting effect. To simplify, generator voltages of ≤ 200 Volts are generated during coagulation, while voltages exceeding 200 Volts are used in cutting mode. The terms RF, High RF and radio waves are essentially interchangeable and refer to high-frequency (HF) waves. There is no distinction between radiofrequency (RF) and radio waves (RW). In European literature, they are commonly referred to as high-frequency waves, while in North American literature, the term radiofrequency is more commonly used. The typical frequency range for medical applications falls between 3 and 300 MHz. Waves above this range are referred to as High RF.

HF Applications in Surgery

Electrosurgery and radiofrequency energy encompass a range within the electromagnetic radiation spectrum. The frequency at which the device operates determines its absorption characteristics, tissue effects, and surgical utility, similar to a laser's medium. Clinicians who are knowledgeable about energy sources often limit or avoid the use of standard monopolar or bipolar devices emitting frequencies below 500 kHz to prevent unintended tissue damage. The interest in various electrosurgical devices and delivery systems stems from the need to control penetration and target tissue effects. It is important to recognize that the frequency of operation primarily governs the unique properties, capabilities, and limitations of the technology.

High-frequency or radiofrequency energy in the frequency range of 1.7 MHz to 4.0 MHz in the radiation spectrum emits non-thermal energy with specific absorption characteristics in water-rich tissues [7]. These frequencies, originally used in ocular plastics, reconstructive, and neurosurgical fields, have been

CHAPTER 7

Endoscopic Management of Basivertebral and Sinuvertebral Neuropathy for Chronic Back Pain

Hyeun Sung Kim[1,*], **Pang Hung Wu**[1,2] and **Il-Tae Jang**[1]

[1] *Harrison Spinartus Hospital Chungdam, Seoul, South Korea*

[2] *Department of Orthopaedic Surgery, Jurong Health Campus, National University Health Systems, Singapore, Singapore*

Abstract: Chronic lower back pain significantly contributes to disability within the musculoskeletal system, affecting a substantial portion of the global population. Among the numerous factors contributing to chronic back pain, degenerative disc disease plays a prominent role, particularly in the aging population. It is hypothesized that the sinuvertebral and basivertebral nerves are the primary mediators of the nociceptive response observed in degenerative disc disease, resulting from the neurotization of these nerves. Extensive research has been conducted to explore the pathoanatomy, pathophysiology, and pain generation pathways involved in degenerative disc disease and chronic back pain. In this book chapter, the authors describe management strategies for sinuvertebral and basivertebral neuropathy and related low back pain symptoms. By examining the current literature, a better understanding of the treatment options and approaches for addressing this condition can be attained.

Keywords: Spondylosis, Sinuvertebral nerve, Basivertebral nerve, Discogenic back pain, The pathophysiology of back pain, And endoscopic spine surgery.

INTRODUCTION

Chronic back pain remains a predominant factor in patient disability within the purview of spinal surgeons [1]. Notwithstanding considerable advancements in healthcare juxtaposed with geopolitical shifts, the incidence of lower back pain as a primary musculoskeletal impairment persistently parallels levels observed from 1990 to 2010 [2]. The underlying causatives of such pain are multifarious, encompassing an intricate interplay of biopsychosocial determinants [3, 4]. Degenerative disc disease is frequently cited as the paramount etiological contributor to lower back pain on a global scale [5]. Consequentially, this form of pain often precipitates symptomatic presentations advocating for lumbar spinal

* **Corresponding author Hyeun-Sung Kim:** Harrison Spinartus Hospital Chungdam, Seoul, South Korea; Tel: 82--6003-9767; Fax: 82-2-3445-9755; E-mail: neurospinekim@gmail.com

Kai-Uwe Lewandrowski & William Omar Contreras López (Eds.)

fusion interventions [5 - 8]. A considerable volume of scholarly discourse emphasizes the integral role of sinuvertebral and basivertebral neuropathic aberrations in the genesis of discogenic lower back discomfort [9 - 17]. This narrative analysis delves into the complex nexus of pathophysiology and therapeutic paradigms pertinent to sinuvertebral and basivertebral neuropathies.

Borenstein *et al*. delineated an intricate taxonomical structure segregating spinal pain into six distinct categories [18]. Commencing with superficial somatic pain, this modality is localized to the dermal and subdermal regions, mediated predominantly by cutaneous A fibers, manifesting acutely in pathologies such as cellulitis or the searing pain seen in herpes zoster. Deep somatic or spondylogenic pain, the subsequent category, encompasses a broader anatomical spectrum including muscles, ligaments, and joints, with the sinuvertebral nerve and the posterior primary ramus (medial branch) as primary mediators. Clinically, this can range from acute presentations in muscular injuries to chronic presentations in degenerative conditions. Radicular pain, ensuing from derangements affecting spinal nerves, typically characterizes conditions such as herniated discs or spinal stenosis. Neurogenic pain, the fourth category, is typified by a burning quality. Viscerogenic referred pain, mediated through autonomic sensory pathways, often presents with a deep, dull quality. Lastly, psychogenic pain occupies the sixth classification. Notably, the subset of patients presenting to spinal surgeons predominantly grapple with deep somatic and radicular pain manifestations, mediated chiefly *via* the medial branch and sinuvertebral conduits for the former and spinal nerve conduits for the latter [18]. The chronicity of such pain can potentiate centralization, culminating in neurotization and heightened nociceptive nerve sensitivity [19 - 21].

Anatomy of the Degenerative Disc

The intervertebral disc serves as a linchpin in biomechanical force modulation, ensuring that the spinal structure remains resilient to dynamic loading and impactive forces encountered during physiological movement [22]. This entity undergoes structural and functional adaptations in response to the quotidian biomechanical demands placed upon the vertebral column [23]. A perturbation in this system, such as degenerative disc disease, can precipitate spinal misalignment [24]. Notably, mature intervertebral discs are devoid of vascularization and neural components; nevertheless, they procure essential nutrients through osmotic gradients from proximal endplate vessels and centrifugally radiating pre-disc vessels [25]. This disc comprises the nucleus pulposus (NP), annulus fibrosus (AF), and cartilaginous endplates from contiguous vertebrae [26]. The etiopathogenesis of degenerative disc disease encompasses:

1. **Non-traumatic degeneration**: Age-related metabolic shifts precipitate alterations in nutrient diffusion and extracellular matrix composition, culminating in disc degeneration (69). An integral component of these degenerative transformations is the spontaneous necrosis of chondrocyte-like entities within the NP, a phenomenon that intensifies with advancing age. Such cellular necrosis catalyzes the deterioration of the cartilaginous-collagenous interface, engendering syndesmophyte genesis and calcific alterations in neighboring vertebral entities [27].
2. **Traumatic degeneration**: Chronic microtraumatic insults beget annular fissures and internal disc disruptions [28, 29]. Both traumatic and insidious onset events induce macroscopic and ultrastructural perturbations in the lumbar intervertebral discs, which precipitate disc degeneration and heightened nociceptive sensitivity. Intrinsically, microscopic aberrations within the disc stimulate cytokine release, inciting immune cell recruitment and amplifying cytokine production. This cytokine milieu fosters neutrophil proliferation, neural invasion, and neural sensitization, all of which synergistically contribute to lumbar discomfort [30, 31].
3. **Additional factors**: Genetic predispositions, chronological aging, smoking, and iterative biomechanical strain cumulatively diminish nutrient acquisition, evoke structural modifications, and incite inflammatory and neovascular responses within compromised discs. These sequelae subsequently manifest as axial discomfort [32].

The inexorable progression of disc degeneration translates to a decline in disc stature [33]. Such a decrement incites a plethora of changes within the spinal microenvironment. A compromised disc stature instigates facet joint micro-subluxation, disrupting the homeostatic balance that hinges on an intact disc for optimal articulatory function [34]. This micro-subluxation is implicated in myriad facet joint pathoanatomical transformations, such as facet hypertrophy, capsular rigidity, and increased segmental stiffness, coupled with muscular contracture in the vicinal region [35]. A heightened propensity for spinal instability is often observed in patients grappling with discogenic lumbar pain [36]. Furthermore, diminished disc stature can occasion ligamentum flavum encroachment into the spinal canal, primarily engendered by disc involution, contributing significantly to ligamentum flavum hypertrophy [37]. Cumulatively, these spinal derangements can span from localized axial discomfort to more diffuse radicular and neurogenic claudication syndromes.

Modic Changes & Discogenic Back Pain

A growing body of literature underscores the discernible alterations in the neighboring vertebral endplates in patients afflicted with discogenic lumbar

CHAPTER 8

The Anatomical Boundaries and Endoscopic Technique of Posterior Cervical Key-Hole Foraminotomy

Li Lijun[1,*], **Ma Ji**[1] and **Shi Bo**[1]

[1] *Orthopedic Spine Department, Shaanxi Provincial People's Hospital, Shaanxi, China*

Abstract: Posterior cervical foraminotomy stands as a recognized decompressive intervention aimed at alleviating radiating symptoms in the arm, neck, and shoulder stemming from refractory cervical radiculopathy. Although it parallels the anterior cervical discectomy and fusion (ACDF) in application, its endoscopic iteration boasts pronounced merits, especially when juxtaposed with ACDF and conventional open foraminotomy. Such benefits are attributed to reduced tissue insult and diminished postoperative discomfort. In this segment, the authors delineate contemporary advancements made in enhancing the endoscopic posterior cervical foraminotomy procedure. Moreover, they furnish an abundant array of intraoperative endoscopic depictions capturing surgically pertinent landmarks and anatomy, supplemented by their radiographic analogs.

Keywords: Cervical radiculopathy, Posterior cervical foraminotomy, Endoscopic decompression, Surgical anatomy.

INTRODUCTION

Posterior cervical foraminotomy stands as an eminent surgical modality addressing nerve entrapment in the cervical spine, with particular emphasis on the intervertebral foramen [1 - 3]. While historically, this intervention mandated a considerable incision accompanied by extensive muscular dissection, contemporary advances in endoscopy have heralded a paradigm shift toward a less invasive rendition of the posterior cervical foraminotomy [2 - 9]. This non-fusion endoscopic adaptation offers a panoply of merits, most notably minimized tissue disruption, attenuated blood loss, and diminished postoperative discomfort [3, 4, 10 - 13].

* **Corresponding author Li Lijun:** Orthopedic Spine Department, Shaanxi Provincial People's Hospital, Shaanxi, China; E-mail: llj_11070715@sina.com

Kai-Uwe Lewandrowski & William Omar Contreras López (Eds.)

This procedure necessitates the excision of both osseous and soft tissue entities infringing upon the spinal nerves nestled within the intervertebral foramen. By architecting augmented clearance at the afflicted locus, posterior cervical foraminotomy endeavors to mitigate the strain on the beleaguered nerve roots, thereby alleviating symptoms like pain, paresthesia, and associated neurological aberrations [14]. The clinical scenarios warranting this intervention encompass a gamut of cervical spine maladies culminating in nerve root oppression [15]. Cervical radiculopathy, often birthed from disc herniations, age-related transformations, foraminal narrowing, or osteophytic accrual in the cervical anatomy, presents saliently with pain radiation, muscular frailty, and sensory perturbations in the brachial region. Additionally, foraminal narrowing secondary to degenerative evolutions like facet joint deterioration, ligamentum flavum thickening, or disc aging also qualifies as an indication for posterior cervical foraminotomy [15]. In the ensuing sections, the authors meticulously delineate the endoscopic iteration of the posterior cervical foraminotomy, accentuating the pivotal surgical landmarks throughout the procedural continuum.

Relationship of Cervical Nerve Roots and Intervertebral Discs

The cervical nerve roots exhibit a defined anatomical juxtaposition to their contiguous vertebral bodies and intervertebral discs. Residing at the apex of their associated vertebral entities, one can locate the spinal nerve ganglia. To elucidate, the genesis of the C5 nerve root is traced to the spinal cord's C4 juncture, while the origins of the C6 and C7 nerve roots are demarcated at the interstices of C4-C5 and C5-C6 intervertebral discs, respectively. Notably, the C8 nerve root has its inception at the C6-C7 disc confluence. These origins harmoniously align with the definitive echelons of vertebrae and discs within the cervical architecture. As C8 nerve roots navigate the C7-T1 foramen, they seldom establish direct liaison with the C7-T1 intervertebral disc.

The spatial orientation of the cervical nerve roots vis-à-vis the intervertebral discs subscribes to a distinct gradient. The superior cervical nerve roots position marginally inferior to the plane of the associated disc, in contrast to the inferior cervical nerve roots that align slightly superior to their respective disc tier. This intricate alignment is adeptly depicted in Fig. (**1**), accentuating the cerebral synergy between the cervical nerve roots and intervertebral discs. A profound grasp of the meticulous anatomical affiliations amongst the cervical nerve roots, spinal ganglia, and intervertebral discs is paramount, serving as a cornerstone for precise diagnostic endeavors and surgical interventions aimed at ameliorating nerve entrapment and affiliated pathologies within the cervical column.

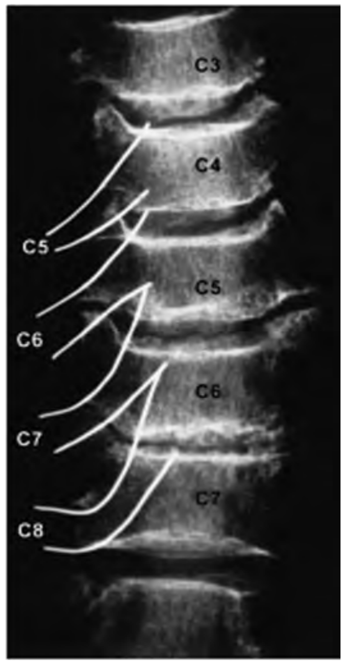

Fig. (1). Anterior-posterior radiograph of the cervical spine with a schematic drawing of the cervical nerve roots and their relationship to the intervertebral disc spaces.

The anatomical interplay amongst cervical nerve roots, intervertebral foramina, and discs, as elucidated by Tanaka *et al.*, requires a more multifaceted understanding than previously comprehended. Morphologically, the intervertebral foramina manifest a funnel-like architecture, with a pronounced narrowing at the ingress zone, whilst the root sheaths assume a tapering configuration. The zenith of the root sheaths' expanse is perceptible at their egress from the central dural sac. Hence, nerve root impingements predominantly transpire at the initial segment of the intervertebral foramina. Anterior encroachment of the nerve roots frequently stems from disc protrusions and osteophytes within the uncovertebral domain. In parallel, posterior neural perturbations owe their genesis to the superior articular process, the ligamentum flavum, and surrounding fibrous matrices. Intriguingly, the C5 nerve roots make their egress juxtaposed to the midsection of the intervertebral disc, whereas the C6 and C7 counterparts navigate adjacent to the disc's commencement. The C8 nerve roots proffer scant engagement with the C7-T1 disc whilst ensconced within the intervertebral foramen. Additionally, the C6 and C7 nerve roots span dual disc tiers within the dural protective casing, and a substantial prevalence of intradural affiliations amid the dorsal radicles spanning the C5, C6, and C7 segments has been described [16]. These anatomical details are adeptly portrayed in Fig. (**2**).

CHAPTER 9

Applied Surgical Anatomy in Full-Endoscopic Posterior Cervical Foraminotomy

Zhen-Zhou Li[1,*] and **Shu-Xun Hou**[1]

[1] *Department of Orthopedics, Chinese PLA General Hospital, Beijing, China*

Abstract: Posterior endoscopic cervical foraminotomy (FE-PCF) has emerged as an alternative to ACDF or open posterior foraminotomy for treating cervical radiculopathy caused by foraminal stenosis or herniated discs. In this chapter, the authors provide an overview of the surgically applied anatomy relevant to the FE-PCF. The procedure involves using advanced endoscopic visualization and surgical instruments to achieve precise decompression of the affected nerve root. Therefore, the authors summarize the key features of posterior endoscopic cervical foraminotomy, including its advantages over traditional open surgery, such as lower complication rates, reduced tissue disruption, and faster recovery times. They employ illustrative step-by-step instructions that the novice endoscopic spine surgeon can employ to execute the posterior endoscopic cervical foraminotomy safely and effectively.

Keywords: Posterior endoscopic cervical foraminotomy, Cervical radiculopathy, Applied surgical anatomy.

INTRODUCTION

Anterior cervical discectomy and fusion (ACDF) and posterior cervical foraminotomy (PCF) are currently the standard surgical procedures for treating cervical radiculopathy. However, studies have shown that both procedures are associated with various postoperative complications, such as restricted neck mobility, reduced intervertebral disc height, vascular, neural, and esophageal injury related to the ACDF approach, adjacent segment degeneration, and surgical scars [1 - 3]. PCF is also associated with complications such as damage to the paraspinal muscles and facet joints, postoperative neck pain, muscle dysfunction, iatrogenic cervical segmental instability, and kyphosis [4].

PCF is a surgical technique that preserves motion at the affected segment. It achieves a 90% relief rate for radicular symptoms caused by soft intervertebral

* **Corresponding author Zhen-Zhou Li:** Department of Orthopedics, Chinese PLA General Hospital, Beijing, China; E-mail: dr_lizhenzhou@163.com

Kai-Uwe Lewandrowski & William Omar Contreras López (Eds.)

disc protrusion, osteophyte hypertrophy, or synovial cysts at the foraminal level [5]. With the continuous improvement of full-endoscopic equipment and surgical techniques, the use of full-endoscopic PCF, or FE-PCF, can significantly reduce iatrogenic soft tissue and facet joint damage in posterior cervical surgery, improve surgical visualization, ensure thorough hemostasis, provide clear neuroanatomy, and achieve effective decompression [6 - 8]. Based on these advantages, full-endoscopic posterior cervical foraminotomy (FE-PCF) can become a minimally invasive treatment option for cervical radiculopathy. There are pros and cons to both surgical treatments:

Advantages

- Compared to anterior cervical discectomy and fusion (ACDF), FE-PCF avoids the risks associated with anterior surgical approaches, such as injury to the esophagus, trachea, and neurovascular structures. Additionally, FE-PCF is also suitable for treating cervical spine lesions above C3 and below C7 [9].
- Compared to PCF, FE-PCF causes less damage to the posterior cervical structures, including muscles, soft tissues, and facet joints. There is a lesser likelihood of exacerbating postoperative cervical kyphosis. FE-PCF can also be used in patients with radiculopathy and non-structural cervical kyphosis, as the relief of radicular pain allows for improved cervical range of motion and preservation of the normal range of rotation center.
- FE-PCF offers clear surgical visualization, easy hemostasis, high anatomical structure identification, high surgical safety, and excellent surgical outcomes.

Disadvantages

- FE-PCF has a narrow surgical field of view, and the steep learning curve is a key limiting factor.
- In patients with foraminal stenosis combined with hypertrophy of the facet joints or narrowing of the intervertebral space, FE-PCF can achieve sufficient decompression, but the surgery may take longer.
- Prior to performing FE-PCF, surgeons need to have sufficient experience in full-endoscopic lumbar surgery, especially in the use of high-speed burr drills. Experience in open or channel-assisted posterior cervical foraminotomy is also required [10].

SURGICAL INDICATIONS

There are well established surgical indications and contraindications for the posterior cervical endoscopic foraminotomy (FE-PCF) procedure [8]. While the absolute indications and contraindications are generally well accepted, relative indications and contraindications may depend on patient-related factors, surgeon skill level, the training of the support staff, and the available infrastructure at the medical facility. An exemplary case is illustrated in Fig. (**1**). In the authors' opinion, the following are the current absolute and relative indications and contraindications for the FE-PCF procedure [11 - 13]:

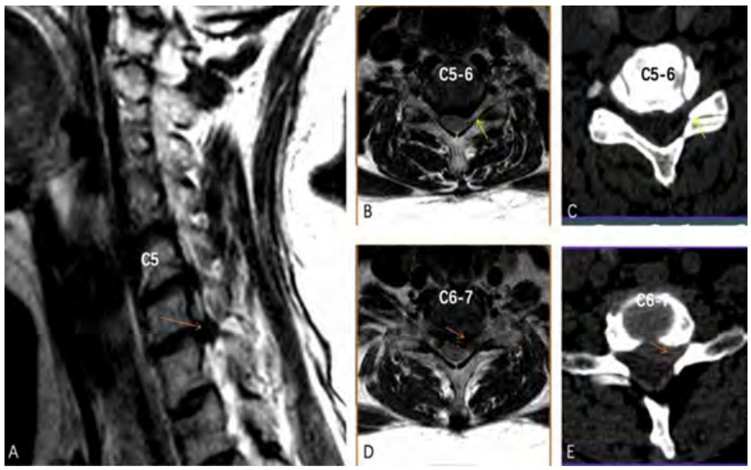

Fig. (1). Etiology of Cervical Radiculopathy. Disc herniation and uncovertebral joint hypertrophy are the main causes of foraminal stenosis. A: Sagittal T2-weighted MRI showing foraminal stenosis at C5-6 and C6-7 levels. B-C: Cervical spondylotic radiculopathy at the left C5-6 foramen due to facet joint and uncovertebral joint hypertrophy. D-E: Cervical radiculopathy at the left C6-7 foramen caused by compression from herniated disc material.

Absolute Indications

- Clear radiographic evidence of foraminal herniation of soft intervertebral disc with corresponding severe radiculopathy symptoms and signs.
- Nerve root compression caused by osteophyte from the facet joint with corresponding radiculopathy symptoms and signs.
- Chronic nerve root compression caused by soft intervertebral disc protrusion or hypertrophy of the uncovertebral joint or osteophyte, unresponsive to adequate conservative treatment.

Relative Indications

- Paracentral cervical disc herniation extending to the foramen, causing corresponding radiculopathy symptoms and signs.
- Foraminal cyst or tumor.
- Presence of high-risk factors or contraindications for anterior cervical surgery, such as professional singers, extensive scar adhesions after thyroid surgery, lesions above C3 or below C7 in patients with a short neck, *etc.*

CHAPTER 10

Identifying the V-Point During Cervical Endoscopic Unilateral Laminotomy with Bilateral Decompression

Vincent Hagel[1,*]

[1] *Asklepios Hospital Lindau, Spine Center, Lindau, Germany*

Abstract: Cervical endoscopic unilateral laminotomy for bilateral decompression (CE-ULBD) is a surgical technique that addresses central canal stenosis, often associated with radiculopathy and myelopathy. Previous studies have demonstrated this method's feasibility, safety, and effectiveness, highlighting its advantages over anterior cervical discectomy and fusion (ACDF) in terms of surgical duration, blood loss, and hospital stay. In this chapter, the author focuses on the surgical steps by illustrating the applied surgical anatomy to enable aspiring endoscopic spine surgeons to lean about the key steps this technique and to perform it safely and successfully. This author recommends having an experienced spine surgeon in the operating room for the first several cases before performing posterior endoscopic decompression of the stenotic central cervical spinal canal alone.

Keywords: Cervical spinal canal stenosis, Spinal cord compression, Cervical myelopathy, CE-ULBD, Laminotomy, Posterior cervical endoscopic decompression.

INTRODUCTION

Degenerative cervical central canal stenosis is a prevalent cause of cervical myelopathy, characterized by the progressive narrowing of the cervical spinal canal and subsequent mechanical compression of the spinal cord [1 - 11]. This condition can lead to symptoms and potential clinical deterioration, including fine motor deficits in the upper extremities, ataxia, lower extremity hypesthesia, and bladder/bowel dysfunction [2, 14]. Various anatomical factors contribute to central canal stenosis in the cervical spine, such as spondylotic changes causing disc bulging or ossification of the posterior longitudinal ligament in the anterior spinal column and hypertrophic ligamentum flavum in the posterior spinal column [5, 5 - 18]. Facet joint hypertrophy rarely contributes to central canal stenosis

* **Corresponding author Vincent Hagel:** Asklepios Hospital Lindau, Spine Center, Lindau, Germany; E-mail: vhagel@yahoo.de

Kai-Uwe Lewandrowski & William Omar Contreras López (Eds.)

[15]. The optimal surgical management for patients with mild stenosis/ myelopathy and normal electrophysiological findings remain unclear, but surgical treatment is recommended for moderate to severe cases [11, 13, 15, 19].

Surgical interventions for cervical central canal stenosis involve ventral or dorsal approaches. While the ventral approach is more commonly preferred by surgeons, there are situations where the posterior approach may be more suitable [2, 13, 19 - 21]. Factors such as the location of maximum compression, stability, and sagittal profile influence the choice of approach [2]. The posterior approach may be indicated in cases of a hypertrophic yellow ligament with or without associated kyphosis [15, 17]. Traditional microsurgical techniques for posterior approaches to the cervical spine often damage the paravertebral musculature, leading to prolonged neck pain, increased kyphosis, or potential instability [22]. However, endoscopic posterior approaches have shown promise in minimizing these drawbacks [23 - 29]. Limited studies have directly compared endoscopic approaches to conventional open techniques in the cervical spine [30, 31]. Still, evidence from other areas of the spine suggests reduced risks of postoperative kyphosis, instability, and infection [32 - 34].

In this chapter, the author illustrates his preferred decompression technique for this condition - the cervical endoscopic unilateral laminotomy for bilateral decompression (CE-ULBD) technique and explains the critical surgical steps and the endoscopically directly visualized anatomy the novice endoscopic spine surgeon will encounter [30, 35].

ENDOSCOPIC INSTRUMENTS

The author's choice is an endoscope designed for posterior cervical surgery. Typically, diameters vary between 7.3 mm and 10 mm. A smaller-sized endoscope offers greater flexibility, facilitating contralateral decompression and causing minimal soft tissue trauma. It lowers the risk of injuring the spinal cord during the operation. A larger-diameter endoscope allows for larger instruments, enabling more aggressive and potentially faster decompression. The surgeon's skill level, preferred technique, and available equipment will ultimately determine which system to employ during spinal cord decompression. Regardless, surgeons should use an endoscopic technology platform to perform cervical spinal cord decompression safely and effectively. Training before entering the operating room for the first time and attempting to perform a CE-ULBD is paramount.

PATIENT POSITIONING

In traditional microsurgical techniques, sitting is often employed to minimize bleeding from epidural vessels during posterior decompression. However, endoscopic procedures can be a simple setup. Instead, patients can be prone, with the head in a slight capital flexion and the subaxial cervical spine extended [36]. Achieving good inclination for accessing the upper levels of the subaxial cervical spine may be challenging, and using a clamp can be helpful in such cases. Sufficient kyphosis can typically be achieved for the lower cervical spine levels using a chest roll without a clamp. It is advisable to avoid extensive pulling or taping down of the shoulder to prevent potential complications like postoperative C5 palsy after cervical decompression, as the role of shoulder traction in this condition remains uncertain [37]. Individualized traction requirements can be assessed under fluoroscopy before draping.

During the endoscopic procedure, continuous irrigation is employed to minimize bleeding. However, in cases where bleeding needs to be controlled, bipolar cautery may be used cautiously, particularly avoiding its use in the epidural space to prevent dural shrinkage and potential neurological deficits. Instead, hemostatic agents should be utilized. Intraoperative monitoring, if available, is recommended to alert the surgeon of any impending harm to the spinal cord, allowing for necessary adjustments in irrigation pressure or even temporarily suspending the procedure.

APPROACH PLANNING

To plan the approach for CE-ULBD, several anatomical landmarks need to be identified. These include the posterior elements' midline spinous process and bilateral lateral masses. These landmarks should be marked on the skin under fluoroscopic guidance in the posterior-anterior view (PA). The intended trajectory (parallel to the target levels disc space) should be drawn in the lateral view of the patient's neck (Fig. **1**).

SKIN INCISION

The placement of the skin incision depends on factors such as the presence of ipsilateral foraminal stenosis and the extent of contralateral decompression required. Typically, the off-midline distance ranges from 0.5 cm to 1.5 cm. A smaller distance is used when ipsilateral foraminotomy is necessary, while a more considerable distance is used when priority is given to contralateral decompression. After making the skin incision, a rigid guiding rod is placed on the facet joint of the target level under fluoroscopic guidance. The placement is usually done in the PA view to ensure accurate positioning on the posterior surface of the facet joint. The rod should be placed towards the lateral aspect of the facet joint to minimize the risk of accidental slippage into the spinal canal, which poses a low risk of vertebral artery injury. This author does not use guidewires to avoid the risk of spinal cord damage. Serial soft tissue dilators are

CHAPTER 11

Full-Endoscopic Cervical Medial Branch Neurotomy

Zhen-Zhou Li[1,*] and **Shu-Xun Hou**[1]

[1] *Department of Orthopedics, Chinese PLA General Hospital, Beijing, China*

Abstract: Full-endoscopic cervical medial branch neurotomy (FECMBN) is a minimally invasive procedure for chronic cervical facet joint pain. The procedure involves advanced endoscopic visualization and surgical instruments to achieve precise neurotomy of the medial branch innervating the cervical pain facet joint complex. In this chapter, the authors summarize the key features of the posterior full-endoscopic cervical medial branch neurotomy, including its advantages over traditional non-visualized radiofrequency-based ablation procedures regarding the treatment effect's safety, efficacy, and durability. They employ illustrative step-by-step instructions that the novice endoscopic spine surgeon can employ to execute the posterior full-endoscopic cervical medial branch neurotomy safely and effectively.

Keywords: Posterior full-endoscopic, Cervical medial branch, Neurotomy, Surgical anatomy, Technique, Outcomes.

INTRODUCTION

The cervical vertebrae's upper and lower articular processes form the cervical facet joint. Each facet joint is enveloped by a fibrous joint capsule, lined with synovium, and contains articular cartilage [1]. Previous studies have shown that the facet joint capsule of the cervical spine contains pain receptors [2]. Three types of synovial folds have been identified, with varying amounts of fibrous and adipose tissue, which may play a role in cervical facet joint pain [3]. Pain mediators such as protein gene product 9.5, substance P [4], and calcitonin gene-related peptide have also been found in the facet joint capsule [4], indicating that the cervical facet joint may be an essential source of neck pain [5]. The cervical facet joints are innervated by the medial branches (MBs) of the dorsal rami of the spinal nerves. Bogduk and Marsland were the first to conduct relevant studies and confirmed the existence of cervical facet joint pain through diagnostic medial branch blocks (MBBs) [6].

[*] **Corresponding author Zhen-Zhou Li:** Department of Orthopedics, Chinese PLA General Hospital, Beijing, China; E-mail: dr_lizhenzhou@163.com

The prevalence of cervical facet joint pain varies greatly. A series of studies using more specific double-blinded, sham-controlled MBBs, as described by Barnsley *et al.*, reported an incidence of cervical facet joint pain ranging from 36% to 55% [7 - 10]. Cervical facet joint pain can result from conditions like hyperextension injuries, like whiplash, or degenerative processes like osteoarthritis [11]. Currently, no treatment method can reverse the pathophysiological processes of facet joint pain [12]. Intra-articular corticosteroid therapy has been advocated but failed to yield positive results in a rigorous evaluation through a randomized, double-blinded, controlled trial [12]. Another palliative neurosurgical approach is the medial branch neurotomy of the dorsal rami, which can interrupt the transmission of pain signals from the painful structures, thus preventing the perception of nociceptive pain and blocking the experience of suffering. Percutaneous radiofrequency neurotomy (PRN) is a neurosurgical technique that utilizes radiofrequency to denature the target nerves, disintegrating distal axons thermally [13, 14]. However, pain may return when axons regenerate and nociceptive pain signal transmission is restored [15 - 17].

According to systematic review studies, there is moderate evidence in support of short-term and long-term pain relief or grades II-1 to II-2 for cervical PRN [18, 19]. Similarly, PRN can provide an effective treatment option for persistent neck pain following anterior cervical spine surgery [20]. The evidence is more substantial if multiple-site ablations are performed according to the descriptions by Lord *et al.*, McDonald *et al.*, Boswell *et al.*, and Barnsley [12, 20 - 22]. Lord *et al.*reported complete pain relief in only 58% of patients, McDonald *et al.* achieved complete pain relief in 71%, and Barnsley reported satisfactory outcomes in 80% of patients [9, 12, 20, 21, 23]. However, cervical PRN is only sometimes effective, with approximately 30% of patients experiencing no therapeutic effect. This may be closely related to improper patient selection, anatomical variations of the MBs, suboptimal positioning of the radiofrequency electrode, incomplete ablation, and regeneration of MBs [24]. Anatomical variations of the lumbar MBs have been identified in cadaveric and endoscopic surgical studies. Variations in MB location can explain the differences in the efficacy of PRN under fluoroscopic guidance [24]. These findings suggest that a minimally invasive spinal surgery alternative guided by full endoscopy can achieve perhaps better and more reliable results.

SYMPTOMS AND SIGNS OF FACETOGENIC NECK PAIN

Classic clinical manifestations of cervical facet joint pain include neck pain originating from the facet joints and referred pain to the head and upper limbs [11]. Patients may experience headaches, limited neck movement, and typical neck pain [24]. The pain is often described as a dull ache in the posterior neck region, sometimes radiating to the shoulders or mid-back. It is essential to consider the history of whiplash injury during the patient interview. Patients may exhibit tenderness over the cervical facet joints or paraspinal muscles. Pain worsens with neck extension or rotation without any signs of neurological impairment.

FULL-ENDOSCOPIC CERVICAL MEDIAL BRANCH NEUROTOMY

The authors first reported full-endoscopic cervical medial branch neurotomy (FECMBN) to treat chronic lumbar facet joint pain [25]. Although the anatomical structures related to the cervical spine may be homologous to the lumbar region, they are not identical [26]. Specifically, the transverse processes of the cervical vertebrae are shorter and located anterior to the facet joints [27]. The authors designed a new endoscopic technique for the neurotomy of the medial branches under endoscopic guidance to achieve a broader range of ablation in the lateral aspect of the cervical facet joints, where the medial branches traverse [27]. Visualization and confirmation of the dorsal ramus and its branches are performed under full-endoscopic guidance, followed by their dissection and ablation. The preliminary results of FECMBN for treating chronic cervical facet joint pain are encouraging. There are pros and cons of the FECMBN:

Advantages

- Endoscopy integrates key elements of surgical procedures, including a cylindrical surgical channel with a light source, camera, irrigation channel, and working channel. This setup ensures precise surgical site localization, clear surgical field visualization, minimally invasive surgical techniques, and minimal iatrogenic injury.
- The procedure is performed under local anesthesia, allowing for patient feedback during surgery, which improves surgical outcomes and helps avoid serious surgical complications.
- Endoscopy enables the exploration of the dorsal ramus and its branches of cervical spinal nerves and selective resection of the medial branches and their branches while avoiding damage to the lateral branches of the spinal nerves, thus preventing complications such as cervical muscle weakness.
- Full-endoscopic cervical medial branch neurotomy (FECMBN) provides better outcomes and longer-lasting effects than PRN procedures.

Disadvantages

- Endoscopic procedures require specialized equipment and instruments.
- Endoscopic surgery has a steep learning curve.

CHAPTER 12

Endoscopic Posterior Cervical Decompression for Ossified Posterior Longitudinal Ligament

Xifeng Zhang[1], **Yan Yuqiu**[2], **Bu Rongqiang**[2], **Zhang Jiajing**[2], **Fan Haitao**[2], **Zeng Qingquan**[2] and **Kai-Uwe Lewandrowski**[3,4,5,*]

[1] *Department of Orthopedics, Wangjing Hospital, China Academy of Chinese Medical Sciences, Beijing, China*

[2] *Department of Minimally Invasive Spine Surgery, Beijing Aiyuhua Hospital, Beijing, China*

[3] *Center for Advanced Spine Care of Southern Arizona and Surgical Institute of Tucson, Tucson, AZ, USA*

[4] *Departmemt of Orthopaedics, Fundación Universitaria Sanitas, Bogotá, D.C., Colombia*

[5] *Department of Neurosurgery in the Video-Endoscopic Postgraduate Program at the Universidade Federal do Estado do Rio de Janeiro - UNIRIO, Rio de Janeiro, Brazil*

Abstract: Ossification of the posterior longitudinal ligament (OPLL) can lead to cervical myelopathy, particularly in cases of multilevel involvement that pose challenges for effective management. Minimally invasive endoscopic posterior cervical decompression has emerged as a potential alternative to traditional laminectomy surgery. In this chapter, the authors present their clinical experience and report on an illustrative consecutive observational cohort study of thirteen patients with multilevel OPLL and symptomatic cervical myelopathy. The Japanese Orthopaedic Association (JOA) score and neck disability index (NDI) were assessed preoperatively and at a final follow-up of two years postoperatively. The results demonstrated significant improvements in the JOA score and NDI, indicating enhanced functional outcomes. No infections, wound complications, or reoperations were reported. While the two-year outcomes were promising and comparable to those achieved with traditional laminectomy, further investigations are required to assess potential long-term limitations.

Keywords: Ossified posterior longitudinal ligament, cervical myelopathy, Posterior cervical endoscopy.

[*] **Corresponding author Kai-Uwe Lewandrowsk:** Center for Advanced Spine Care of Southern Arizona and Surgical Institute of Tucson, Tucson, AZ, USA; Departmemt of Orthopaedics, Fundación Universitaria Sanitas, Bogotá, D.C., Colombia and Department of Neurosurgery in the Video-Endoscopic Postgraduate Program at the Universidade Federal do Estado do Rio de Janeiro - UNIRIO, Rio de Janeiro, Brazil; E-mail: xifengzhang301@163.com

Kai-Uwe Lewandrowski & William Omar Contreras López (Eds.)

INTRODUCTION

Ossification of the posterior longitudinal ligament (OPLL) is a complex condition characterized by the calcification and ectopic hyperostosis of the posterior longitudinal ligament, leading to cervical spinal canal stenosis [1]. Symptomatic patients experience clinical signs of myelopathy, with or without radiculopathy. OPLL can occur at various locations within the cervical spine, including the posterior disc space or behind the vertebral body, affecting single or multiple levels in contiguous or interrupted patterns. Skip levels, genetic factors, and potential familial disposition have also been implicated. While the condition predominantly affects the cervical spine, it can also manifest in the thoracic spine. Genetic factors and a familial disposition have been suggested [2].

Historically, posterior cervical laminectomy has been the preferred surgical option, especially for patients with multilevel OPPL and long-segment anterior cervical spinal cord compression [3 - 5]. However, this procedure is associated with several complications, including wound-related issues, infections, long-term muscle atrophy, and postoperative kyphosis. The development of acute anterior kinking of the cervical spinal cord can lead to a decline in neurological function. Nowadays, a common approach involves combining posterior cervical laminectomy with instrumented fusion, primarily used in cases of cervical spondylotic myelopathy [2]. Fusion procedures have drawbacks, such as a higher complication rate, including C5 nerve palsy and the potential for adjacent segment disease necessitating additional surgeries shortly after the initial operation, similar to multilevel ACDF [6 - 8].

Nevertheless, some experts argue that fusion is unnecessary as the cervical spine is inherently stable in patients with multilevel OPLL, and excellent long-term prognoses can be achieved without fusion [8]. Laminoplasty has been proposed as a less complex alternative, although patients often report experiencing axial neck pain after the procedure [9]. Minimally invasive decompression surgeries have gained attention to address these issues, although they are typically focused on treating specific pathologies like herniated discs or foraminal stenosis [10 - 14]. Endoscopic surgery has emerged as an alternative to formal open decompression and fusion surgery because modern technology, including high-speed drills and effective rongeurs, nowadays enables the surgeon to perform intricate decompression maneuvers on both bony and soft tissue structures. In this chapter note, the authors present their posterior percutaneous endoscopic technique to achieve minimally invasive decompression across multiple levels in symptomatic OPLL patients. This innovative non-fusion technique offers a promising alternative for patients requiring surgical intervention with reduced tissue disruption, less bleeding, postoperative pain and faster recovery.

CLINICAL PRESENTATION

Clinical symptoms associated with (OPLL) can vary depending on the extent and location [1]. OPLL is characterized by ectopic hyperostosis and calcification of the posterior longitudinal ligament, leading to cervical spinal canal stenosis and subsequent spinal cord and nerve root compression. Common clinical symptoms can range from neck pain with or without radiculopathy, stiffness, and limited range of motion to more subtle hallmark findings of cervical myelopathy, including sensory abnormalities, loss of balance, and fine motor control skills [1]. Patients may need help with tasks requiring precise hand movements, such as writing, buttoning clothes, or manipulating small objects. In advanced cases, patients may experience progressive weakness and numbness in the upper and lower extremities, gait disturbances, loss of coordination, or bladder and bowel dysfunction [1]. This great variety of symptoms often leads to delays in diagnosis, as other medical conditions can also produce similar symptoms because of their insidious onset. Patients may develop radiculopathy with pain, numbness, and weakness radiating along the affected nerve root dermatomal distribution if the OPLL causes compression of the nerve roots as they exit the spinal canal through the intervertebral foramina. Patients often describe these radicular symptoms in the neck, shoulder, arm, and hand. Other more conspicuous symptoms include chronic neck pain and stiffness. This pain can be localized or radiated to the shoulders and upper back. Spinal cord compression as a leading cause of disabling neck pain that is often overlooked as other arthritic conditions produce similar conditions. However, depending on the degree of spinal cord compression and associated inflammation, patients may develop variable neck stiffness with pain in the neck and the shoulders projecting into the upper torso.

Surgeons should suspect OPLL and consider in their differential diagnosis if patients additionally present with a limited range of motion. Patients complaining of difficulty rotating or tilting their necks and associating it with reducing their ability to perform daily activities and reporting reduced quality of life should be worked up for OPLL with advanced imaging studies since cervical myelopathy is the most significant clinical manifestation of OPLL. Compression and dysfunction of the spinal cord in the cervical region can lead to a variable clinical presentation, with some patients being asymptomatic despite radiological evidence of spinal cord compression and others having the full range of myelopathy symptoms. The severity and progression of symptoms depend on factors such as the extent of ossification, the degree of spinal cord compression, and individual variations in the spinal canal size and tolerance to compression. Early diagnosis and appropriate management are crucial to prevent further neurological deterioration and optimize patient outcomes.

CHAPTER 13

Unilateral Laminotomy for Bilateral Decompression

Xifeng Zhang[1], **Yan Yuqiu**[2], **Bu Rongqiang**[2], **Zhang Jiajing**[2], **Fan Haitao**[2], **Zeng Qingquan**[2] and **Kai-Uwe Lewandrowski**[3,4,5,*]

[1] *Department of Orthopedics, Wangjing Hospital, China Academy of Chinese Medical Sciences, Beijing, China*

[2] *Department of Minimally Invasive Spine Surgery, Beijing Aiyuhua Hospital, Beijing, China*

[3] *Center for Advanced Spine Care of Southern Arizona and Surgical Institute of Tucson, Tucson, AZ, USA*

[4] *Departmemt of Orthopaedics, Fundación Universitaria Sanitas, Bogotá, D.C., Colombia*

[5] *Department of Neurosurgery in the Video-Endoscopic Postgraduate Program at the Universidade Federal do Estado do Rio de Janeiro - UNIRIO, Rio de Janeiro, Brazil*

Abstract: Unilateral biportal endoscopic lumbar discectomy (UBE) is a minimally invasive surgical procedure for treating lumbar disc herniation that is associated with bony and soft tissue stenosis. This technique best suits surgeons who want to take advantage of their great experience with the translaminar approach. It simplifies the endoscopic learning curve by placing the endoscopic working cannula onto the posterior spinal elements rather than placing it into the neuroforamen. This chapter describes the technical and procedural aspects of UBE by providing a detailed overview of the procedure, its indications, contraindications, surgical steps, and potential complications. Furthermore, we highlight the advantages and limitations of this innovative technique and discuss its established role in spinal surgery.

Keywords: Endoscopic lumbar discectomy, Trephines, Foraminoplasty, Herniated disc.

INTRODUCTION

Percutaneous endoscopic unilateral interlaminar approach to bilateral lumbar spinal canal decompression (Endo-ULBD) is used to expand the spinal canal and relieve nerve compression in cases of lumbar spinal stenosis. This condition is characterized by the narrowing of the spinal canal or nerve root canal due to bone or fibrous tissue growth, leading to the compression or irritation of the nerves

* **Corresponding author Xifeng Zhang:** Department of Orthopedics, Wangjing Hospital, China Academy of Chinese Medical Sciences, Beijing, China; E-mail: xifengzhang301@163.com

passing through it. Lumbar spinal stenosis is a common cause of low back and leg pain [1]. Traditional treatment methods for lumbar spinal stenosis include lumbar laminectomy or resection, partial facet joint resection, and fusion procedures. However, decompression alone is preferred over fusion when the lumbar spine is stable. Long-term follow-up studies have shown that decompression alone yields similar outcomes to decompression with fusion but with shorter operation times, less bleeding, and lower costs.

The severity of lumbar spinal canal stenosis is classified into four categories (A, B, C, and D) based on the appearance of the dural sac on MRI T2 images [2 - 4]. The more severe the stenosis, the more pronounced the symptoms and the greater the likelihood of requiring surgery. However, the degree of stenosis does not always correlate directly with the symptoms experienced by the patient. The ligamentum flavum, a ligament in the spinal canal, significantly contributes to lumbar spinal stenosis, accounting for 50%-85% of cases. Advancements in minimally invasive spinal surgery have led to the emergence of endoscopic treatments for lumbar spinal stenosis. The ULBD technique was first introduced in 1988, and the surgical methods were first described by De Antoni [5]. Subsequently, in 2002, Khoo *et al.* performed bilateral spinal canal decompression using a microscope from a unilateral interlaminar approach [6]. Since 2005, Professor Rutten and colleagues have published articles explaining the use of spinal endoscopy through intervertebral foramina and interlaminar spaces to treat lumbar spinal stenosis [7 - 11].

The main focus of surgery for lumbar spinal stenosis is addressing the ligamentum flavum and lateral recesses. Total spinal endoscopy has proven to be an effective option for treating this condition, with outcomes comparable to those of microsurgical techniques. It offers operation time, tissue trauma, and rehabilitation advantages, reducing postoperative complications and revision rates. In a study conducted in 2010 by Peng *et al.*, satisfactory postoperative outcomes were achieved in patients with bilateral symptomatic lumbar lateral recess stenosis using the unilateral percutaneous spinal endoscopic decompression through the posterior interlaminar bilateral decompression approach [12]. The Endo-ULBD technique and total spinal endoscopy have emerged as effective and minimally invasive treatment options for lumbar spinal stenosis, offering advantages over traditional open surgical approaches.

INDICATIONS

The indications for the Unilateral Biportal Endoscopic (UBE) approach in treating lumbar spinal stenosis include cases where conservative treatment has proven ineffective for at least three months. Additionally, patients who experience recurrent and frequent episodes of neurogenic claudication or nerve root symptoms, resulting in significant impairment of their daily life and work, may be suitable candidates for UBE [13]. Motor dysfunction and intermittent claudication occurring after walking less than 200 meters are also indications for considering UBE as a treatment option. In the authors' opinion, the indications for surgical intervention in lumbar spinal stenosis employing the UBE technique include the following:

1. Conservative treatment has been ineffective for three months, or if there has been temporary relief but recurrent and frequent episodes of neurogenic claudication or nerve root symptoms.

2. Symptoms significantly impact the patient's daily life and ability to work.

3. Patients experiencing motor dysfunction.

4. Patients with intermittent claudication that occurs after walking less than 200 meters.

Based on the anatomical and pathological conditions prior to surgery, it is evident that the interlaminar pathway can be utilized for decompression. This approach is suitable for lateral and central lumbar spinal stenosis caused by bone hyperplasia, ligamentum flavum thickening, and mild spondylolisthesis (Grade I).

However, there are specific contraindications to consider before proceeding with surgery. These contraindications include:

1. Patients whose primary symptom is solely low back pain.

2. Cases with evident segmental instability or spondylolisthesis of Grade II or higher.

3. Isthmic spondylolisthesis.

4. Severe spinal deformities.

A comprehensive preoperative evaluation and treatment plan involves a detailed medical history and physical examination. Patients should be vetted for contraindications or risk factors according to the inclusion and exclusion criteria. Diagnostic imaging studies such as X-rays, MRI, or CT scans should be evaluated to identify the specific painful spinal pathology. Diagnostic injections are essential to validate suspected pain generators suggested by advanced imaging studies. A comprehensive preoperative evaluation and treatment plan should be implemented before surgery. The following steps should be taken:

CHAPTER 14

Endoscopic Posterior Lumbar Interbody Fusion (PLIF)

Li Lijun[1,*], **Jia Kai**[1] and **Guo Chaofan**[1]

[1] *Orthopedic Spine Department, Shanxi Provincial People's Hospital, Shanxi Medical University, Shanxi, China*

Abstract: Endoscopic Posterior Lumbar Interbody Fusion (PLIF) is a minimally invasive surgical technique to fuse the lumbar vertebrae. This approach combines endoscopy with the established PLIF procedure, reducing tissue damage, improving visualization, and direct neural decompression. The smaller incision size, precise visualization, and specialized endoscopic tools contribute to decreased postoperative pain, faster recovery, and potentially improved patient outcomes. In this chapter, the authors highlight the technical pearls of the endoscopic PLIF by going through the surgery step-by-step with illustrative clinical and intraoperative examples. The authors encourage novice surgeons to obtain specialized training and the necessary equipment to mitigate the potential risks and complications, including damage to neural elements, spinous process fractures, and implant-related problems. While the clinical examples presented herein had excellent functional outcomes and considerable reductions in preoperative pain levels, further research is needed to evaluate the long-term efficacy and outcomes of endoscopic PLIF compared to traditional open procedures.

Keywords: Endoscopic lumbar surgery, Posterior lumbar interbody fusion, Technique, Unilateral access, Bilateral decompression.

INTRODUCTION

After more than 80 years of development, the traditional open posterior lumbar interbody fusion (PLIF) is the classic technique [1]. It is considered the gold standard for lumbar decompression and fusion surgery [2]. It involves the removal of most of the inferior articular processes of the superior segment, a small portion of the superior articular processes and spinous processes of the inferior segment and the upper and lower portions of the laminae [3, 4]. The central and lateral spinal canal is decompressed, and in general, only the traversing nerve roots and the dural sac are exposed. The interbody space is reached by retracting the exiting nerve root laterally when seen and the traversing nerve root medially. The advan-

* **Corresponding author Li Lijun:** Orthopedic Spine Department, Shanxi Provincial People's Hospital, Shanxi Medical University, Shanxi, China; E-mail: llj_11070715@sina.com

Kai-Uwe Lewandrowski & William Omar Contreras López (Eds.)

tage of the posterior approach is the complete decompression of the lumbar spinal canal, *i.e*., the nerve roots can be decompressed and released very clearly bilaterally. However, the open exposure is associated with more bleeding, and higher infection- and complication rates. The advantages of spinal endoscopy-assisted PLIF (Endo-PLIF) are [5, 6]:

1. The posterior approach is a traditional classical technique. It is easy to master, and a short learning curve.
2. The posterior approach has no important local anatomy and is relatively safe, and compared to endoscopic TLIF (Endo-TLIF), there is no need to worry about interference with the exiting nerve root during the approach.
3. The same surgical incision can be chosen as the percutaneous fixation screw, reducing the number of incisions.
4. There is no need to consider too much the influence of the paracentesis distance on the procedure.
5. Unilateral access with bilateral decompression (ULBD) can be chosen according to the specific situation, which is the biggest advantage over Endo-TLIF [7].

Endo-PLIF Rationale

Numerous enthusiastic endoscopists have explored the application of endoscopic-assisted fusion techniques [8 - 12]. However, in its early stages, endoscopic-assisted fusion faced various challenges relating to philosophy, instrumentation, and technology [13 - 16]. Consequently, it needed further advancement. Over the years, as spinal endoscopy techniques have undergone extensive refinement with the development of advanced instruments and other ancillary technology, including navigation [17], robotics [18 - 21], HD optics [22], and most importantly, 3D-printed [23] and expandable implants [6, 9, 24 - 28] have evolved, simple decompression alone can no longer keep up with the progress of spinal endoscopic technology. Fusion, once a hindrance to endoscopic technology development, has now been overcome with the maturation of spinal endoscopic fusion techniques. As a result, endoscopic-assisted fusion has emerged as a safe, reliable, and minimally invasive spinal technique that has been widely promoted and applied [14, 16, 17, 29 - 40]. Furthermore, the tools and techniques used in spinal endoscopy have evolved in tandem, complementing each other in a remarkably similar developmental process. This process is briefly described concerning the different diameters of spinal endoscopes (Figs. **1**-**5**).

Fig. (1). ISEE™ - Channel OD 7.5mm, Mirror OD 6.3mm.

Fig. (2). PLUS™ - Channel T OD 8.6mm, U OD 9.5mm, Mirror OD 7.3mm.

Modern Endoscopes

Small channel endoscopes include TESSYS™ and ISEE™, with an outer diameter (O.D.) of 7.5 mm. These types of endoscopes are mainly used for simple decompression of the intervertebral foramen and interlaminar space, with the advantage of being more minimally invasive and the disadvantage of being less efficient for extensive bony decompression (Figs. **1**, **4**, and **5**). Medium-channel endoscopes, including PLUS-UT™ and other endoscopes with OD 8.6mm, OD 9.5mm, and the Mirror™ endoscope OD 7.3 mm, take into account the respective advantages of small and large channels. In the early days, these types of endoscopes were designed for simple decompression, and can be used for intervertebral foramen and interlaminar approach. Their main advantage is that they are useful for both lateral and posterior approaches. One of their disadvantage is that more bony removal may be required (Figs. **2**, **4**, and **5**).

CHAPTER 15

Percutaneous Spinal Endoscopic Procedures in Adjacent Segmental Disease after Lumbar Fusion

Xueqin Rong[1,*], **Lingan Huang**[2] and **Litao Zhao**[1]

[1] *Department of Pain Medicine Center, The Central Hospital of Sanya, Sanya City. Hainan Province, China*

[2] *Department of Sports Medicine, Beijing Key Laboratory of Sports Injuries, Peking University Third Hospital, Beijing, China*

Abstract: Adjacent segment degeneration and disease (ASD) following spinal fusion surgery can pose challenges, and various surgical approaches have been developed to address this condition. This chapter presents a comprehensive review of the current literature, including clinical studies, comparing the outcomes of endoscopic and open surgical techniques in patients affected by ASD. The authors' analysis reveals that endoscopic surgery demonstrates comparable effectiveness in pain relief, functional improvement, and patient satisfaction while offering potential advantages such as reduced tissue trauma, shorter hospital stays, and faster recovery times. This chapter also discusses each surgical approach's technical aspects, potential complications, and limitations in comparison to endoscopic decompression surgery for ASD. The evidence suggests that endoscopic surgery is a viable alternative to conventional open surgery for treating adjacent spondylosis. However, further research and long-term follow-up studies are necessary to better establish its long-term efficacy and durability.

Keywords: Adjacent segment degeneration, Endoscopic decompression, Surgical technique.

INTRODUCTION

Degenerative diseases of the lumbar spine are a group of diseases that lead to the degeneration and hyperplasia of adjacent small joints and posterior structures based on disc degeneration [1]. Consequently, these conditions result in disc herniation, lumbar instability, compression of nerve tissue, and causing symptoms such as lumbar pain and neurogenic claudication. These include lumbar disk herniation (LDH), lumbar spinal stenosis (LSS), lumbar spondylolisthesis (LS), lumbar instability (LI), degenerative lumbar scoliosis (DLS), *etc.* Reports indicate

* **Corresponding author Xueqin Rong:** Department of Pain Medicine Center, the Central Hospital of Sanya, Sanya City. Hainan Province, China; E-mail: 13912048078@163.com

Kai-Uwe Lewandrowski & William Omar Contreras López (Eds.)

that approximately 3.63% (266 million) of the world's population is affected by degenerative lumbar spine diseases, which significantly affect the quality of life of middle-aged and elderly individuals because of symptoms such as low back pain and intermittent neurogenic claudication [2].

Lumbar interbody fusion is the classic surgical procedure for treating degenerative lumbar spine disease, achieving adequate decompression of neural tissue and stable fusion between vertebrae [3 - 5]. Briggs and Milligan first described posterior lumbar interbody fusion (PLIF) in 1944 as a chronic lower back pain treatment [6]. After over 70 years of development, PLIF has become the accepted gold standard procedure for treating degenerative lumbar spine diseases. With advancements in bone grafting materials, fusion techniques, and endosseous materials (such as interbody fusion and pedicle screws), several approaches have emerged, including transforaminal lumbar interbody fusion (TLIF) [7 - 10], minimally invasive transforaminal lumbar interbody fusion (MI-TLIF), lateral lumbar interbody fusion (LLIF), oblique lumbar interbody fusion (OLIF), *etc* [4, 11]. Interbody fusion of degenerated segments is an effective motor stabilization and pain relief treatment. The aim is to indirectly achieve neural tissue decompression and restore anterior spinal convexity or correct deformities.

Adjacent Segmental Disease (ASD) after Lumbar Fusion

Biomechanical changes in the spine caused by lumbar fusion may inevitably increase the mobility of the adjacent segment and the pressure on the adjacent disc, accelerating its degeneration and leading to the development of adjacent segment disease (ASD) [12 - 14]. ASD is a potential long-term complication of lumbar fusion, including a degenerative disease of the adjacent segment, fracture, infection, and scoliosis or kyphosis, significantly impacting the long-term outcomes of patients after lumbar fusion. Researchers have classified ASD into radiological ASD (R-ASD), symptomatic ASD (S-ASD), and operative ASD (O-ASD) [14, 15]. According to various studies, the incidence of O-ASD after lumbar fusion ranges from 5.2% to 49% [15].

The exact etiology of ASD is unknown; however, fusion-induced changes in spinal biomechanics, including increased loading of adjacent synovial joints, increased intradiscal pressure, and hypermobility of the fused adjacent segment, are considered crucial [16, 17]. Previous studies have demonstrated that the development of ASD after TLIF may be influenced by several factors, including individual factors (age at surgery, body mass index (BMI), osteoporosis, history of smoking, and history of hypertension), preoperative adjacent disc degeneration, long-segment fusion, laminectomy decompression beyond the fused segment, and the presence of preoperative disc degeneration [16. 17]. Furthermore, Laminectomy decompression, intraoperative disruption of the superior tuberosity, and changes in spinopelvic parameters, such as the sagittal vertebral axis (SVA), lumbar lordosis (LL), pelvic tilt (PT), and sacral slope (SS), contribute to the risk. Nevertheless, the risk factors for ASD development after TLIF remain controversial.

ASD after a lumbar fusion can lead to the re-emergence of symptoms such as low back pain and intermittent neurogenic claudication. In some cases, patients are bedridden for years, significantly affecting their quality of life. Patients with ASD whose strict conservative treatment is ineffective after more than three months and whose ASD symptoms severely affect their work and life or even cause cauda equina syndrome can be considered for revision surgery. The choice of the surgical approach for revision surgery, whether a lengthy open surgery or minimally invasive endoscopic surgery, depends on factors related to the initial surgery, patient factors, and possible complications [18 - 20].

Treatment Strategies for ASD

When post-operative ASD occurs, conservative treatment should be prioritized for at least three months. If conservative treatment is ineffective, the patient's pathology, age, physical condition, and other factors should be considered when selecting the appropriate surgical approach. Surgical options include:

- Posterior decompression and fusion.
- OLIF/LLIF fusion.
- Percutaneous endoscopic lumbar discectomy (PELD).
- Microendoscopic decompression of the spinal canal.
- Minimally invasive endoscopic surgery.

Posterior Decompression Fusion: Posterior decompression fusion, including PLIF, TLIF, and MI-TLIF, is often the preferred procedure for surgeons treating post-fusion ASD in patients with degenerative lumbar spine disease who require fusion surgery. This approach aims to restore intervertebral height and decompress nerves while preserving posterior support structures. However, during revision surgery, one of the main challenges lies in avoiding the difficulty of choosing the same surgical approach because of the difficulty in identifying anatomical structures in the surgical region caused by scar tissue formation from the previous surgery. Such scar tissue may lead to adhesions between the neural tissue and the scar, increasing the risk of intraoperative complications such as nerve injury and dural rupture. Furthermore, extending fixed fusion to the adjacent segment may lead to the developing of a new ASD.

CHAPTER 16

Combined Paramedian and Posterolateral Endoscopic Approach to Calcified Central Thoracic Herniation

Thiago Soares Dos Santos[1,*], **Pablo Mariotti Werlang**[1] and **Marlon Sudário de Lima e Silva**[2]

[1] *Regina Hospital, Novo Hamburgo, Rio Grande Sur, Brazil*

[2] *CLINCOL (Endoscopic Spine Clinic), Bogotá, D.C., Colombia*

Abstract: Thoracic endoscopic discectomy is gaining more popularity. Accessing the thoracic spine through a small skin incision rather than large exposures required for the traditional costotrasversectomy approach, the endoscopic technique alleviates pain and neurological symptoms and improves patient outcomes by targeting the compressive pathology directly. In this chapter, the author reviews the indications for the procedure, the inclusion and exclusion criteria, and its technical caveats by illustrating the application of endoscopic instruments and visualization systems. Preoperative evaluation, including advanced imaging techniques, is crucial for accurate diagnosis and surgical planning. Further, the author demonstrates the procedure's advantages, such as reduced tissue trauma, decreased blood loss, shorter hospital stays, and faster recovery than traditional open surgery. With appropriate patient selection and skilled surgical expertise, thoracic endoscopic discectomy is capable of managing thoracic disc herniation with comparable clinical outcomes compared to open techniques without collateral tissue trauma.

Keywords: Thoracic endoscopic discectomy, Thoracic disc herniation, Collateral tissue trauma, Endoscopic instruments, Visualization systems.

INTRODUCTION

Symptomatic thoracic disc herniations are an uncommon pathology, representing 1% of disc herniations in the spine [1]. However, when surgery is highly complicated for most surgeons. The anatomical aspects of the thoracic spine make it challenging to access the hernia in many cases. The type of surgery will depend

* **Corresponding author Thiago Soares Dos Santos:** Regina Hospital, Novo Hamburgo, Rio Grande Sur, Brazil; E-mail: thssantos78@gmail.com

Kai-Uwe Lewandrowski & William Omar Contreras López (Eds.)

on the location, nature of the hernia, clinical picture, complicated training, clinical experience, and personal preference.

Conventional techniques are as follows: posterolateral, lateral transthoracic, and anterior approaches. The microscopic or video-assisted posterolateral approach has low morbidity but is restricted to posterolateral hernias without calcification [2 - 7]. Cases of central hernias, with or without calcification and with or without migration, are complicated and commonly approached through transthoracic accesses that can be video-assisted, but they are procedures with high morbidity.

In the last decade, complete spinal endoscopic procedures have grown exponentially [8 - 15]. There was a technical evolution and improvement of the equipment, expanding its use. There needs to be a consensus on the technique to be used, especially in more complicated cases, such as central hernias. This chapter aims to describe a complete endoscopic technical option to approach central hernias, with or without calcification and with or without migration, which occupy less than 40% of the medullary canal (giant hernias) and to summarize the indications, inclusion and exclusion criteria

Indications

Endoscopic thoracic discectomy is recommended for patients who suffer from ongoing and severe symptoms caused by a herniated disc in the thoracic spine. These symptoms can include intercostal radiculopathy. Myelopathy symptoms that affect the spinal cord. Patients may experience numbness, weakness, or a loss of balance and fine motor control. The gait cycle may also be grossly abnormal due to impaired proprioception. Patients whose symptoms cannot be managed conservatively with physical therapy, gait- and balance training, non-steroidal anti-inflammatories (NSAIDs), and targeted spinal injections may be considered for endoscopic thoracic discectomy surgery.

Contraindications

Contraindications to endoscopic thoracic endoscopy include severe spinal instability, significant spinal deformity, spinal infection or active systemic infection, and the presence of a large disc herniation occupying more than 40% of the spinal canal. Patients with extensive scarring from prior surgeries or interventions in the thoracic region may also not be suitable. Additional relative contraindications may exist due to the patient's prior medical history and comorbidities. Therefore, each patient's medical history, physical examination findings, and diagnostic imaging results should be carefully examined to determine if there are any risk factors for poor outcomes with the endoscopic thoracic discectomy. The discussion about relative contraindications should play out in the context of critically evaluating the surgeons' skill level.

Caveats

The endoscopic technique for thoracic disc herniation is applicable at various levels except for T1/2 due to the risk of damaging the T1 nerve root and limited intercostal space. Since the introduction of the transforaminal endoscopic technique by Choi *et al.* in 2010, it has been widely accepted as the preferred approach for non-calcified centrolateral disc herniations [16]. Approximately 40% of thoracic disc herniations involve calcification, and in most cases, these can still be treated using the endoscopic approach, except in extensive ossification of the posterior longitudinal ligament [17 - 19]. When dealing with calcified disc herniations with dural adhesion, a technique known as "floating" can be employed [20], where the disc is removed while leaving the calcified shell if it is detached from the disc and posterior longitudinal ligament. This approach has shown significant improvement. Central herniations pose a greater challenge as they require a smaller angle for access. Loose soft fragments can be effectively removed using the transforaminal technique. However, for effective decompression in cases of partially or fully calcified discs, central enucleation alone may not suffice. To address this, we propose a technique utilizing two endoscopic accesses: one paramedian and the other posterolateral. In some instances, there may be combined ossification of the ligamentum flavum, which can be removed through the paracentral approach.

From a technical perspective, the difficulty of accessing the central region of the spinal canal increases with a greater angle of attack. Hernias that have not fully calcified are relatively easier to remove. To address this, we propose utilizing a paramedian access approach to remove the roof and floor of the foramen effectively. This approach proves particularly beneficial in the cranial migration of the hernias, as depicted in Fig. (**7**). In Figs. (**8** and **9**), partial calcification of the hernias is evident through CT imaging. It is essential to focus on the head of the rib, especially at levels above T10, as well as the cranial vertebra's body, pedicle, and caudal vertebral body. This strategy facilitates navigation through the posterolateral access and simplifies the removal of partially or fully calcified central hernias that have experienced migration.

Preoperative Target Planning

The initial step in the surgical planning for thoracic disc herniation is to analyze the imaging examinations, specifically Computed Tomography (CT) and Magnetic Resonance Imaging (MRI). These imaging modalities provide:

SUBJECT INDEX

D

E

K

L

M

N

O

P

R

S

T